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STUDY S-382

STUDY OF DoD AUTOMATED ENVIRONMENTAL SERVICES SUPPORT SYSTEMS

Report of Findings

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June 1971

INSTITUTE FOR DEFENSE ANALYSES
SCIENCE AND TECHNOLOGY DIVISION

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13. ABSTRACT

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Subjects reviewed are: The current operations of the Fleet Numerical Weather Central and the Air Force Global Weather Central, the DoD needs for environmental services, potential data sources which the Services might utilize to meet military needs in 1975, data processing equipment and personnel requirements based on military needs for this same period, costs of the various options open to DoD, and a review of the pros and cons of these options.

It is concluded that collocation/consolidation of the presently constituted centers would not be cost-effective.

It is recommended that cost/benefit analyses of the military needs for environmental data be performed to determine the extent to which improved capabilities which are forecast to be technologically available in 1975-80 should be implemented. If, on the basis of this analysis, the currently stated military needs are to be fully met, DoD should proceed with acquisition and installation of advanced computers and of satellite readout facilities for operational environmental services support at an investment cost over the next eight years of approximately $90 million.

It is concluded that the satisfaction of the premised needs may be physically realizable in terms of current state of the art by either separate or consolidated centers. Differences in equipment and cost required to meet premised needs, in the light of prediction uncertainties, are not of themselves sufficiently compelling to be the basis for the choice; instead, it is concluded that the choice should be made based on other management considerations.

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READER'S REFERENCE

This Study of DoD Automated Environmental Services Support Systems consists of the following documents:

Report of Findings

Appendix A. DoD Needs for Environmental Support Services

Appendix B. Navy Environmental Support Services in 1970

Appendix C. Air Force/Army Environmental Support Services in 1970

Appendix D. Sources of Data for DoD Environmental Services Support Systems of 1975-80

Appendix E. Numerical Simulation of Global Circulation of the Atmosphere up to an Altitude of 300 km

Appendix F. Data Processing for DoD Environmental Services Support Systems of 1975-80

Appendix G. Costs of a Spectrum of Options for Data Processing of DoD Environmental Services Support Systems of 1975-80

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SUMMARY

This study examines the feasibility of collocation and/or consolidation of the Navy and Air Force operational environmental services computer centers.

The methodology adopted to accomplish this task involved six steps. First, the current operations at the Fleet Numerical Weather Central (FNWC) at Monterey and at the Air Force Global Weather Central (AFGWC) at Omaha were examined and compared. Second, a collation of military needs for environmental data, both current and forecasted, was made. The third step involved an analysis of potential new data sources, specifically satellite systems and ocean data collection buoy systems. In step four, the implications of potential military needs and the potential capabilities of new data sources were related to computer capacity requirements and 1975 capabilities to arrive at an estimate of machine and personnel needs realizable in 1975. In step five, organizational ways of meeting 1975 requirements, i.e., the options open to DoD decision makers, were considered. In step six, costs of the alternative organizational configurations were analyzed, and the pros and cons of each option were reviewed. Configurations and operations described are as of December 1970.

CURRENT OPERATIONS

FNWC

The analysis of the Fleet Numerical Weather Central shows that the demands on Naval Weather Service computing facilities exceed the equipment capability to satisfy those demands. The equipment is currently being used close to its peak of efficiency, although there is some overlap with parallel activities at Air Force Global Weather Central. The Automated Weather Network (AWN) data base on which all the weather service and oceanographic services is founded is precariously dependent on cooperation of foreign nations through the World Meteorological Organization.

Preprocessing of data input to the main computer system occupies only a small fraction of the total computer capacity. The time of availability of the pre-processed input data is limited by the rate of delivery of such data. Current communications systems are inadequate for the transmission of currently available satellite data.

AFGWC

The Air Weather Service, including the Air Force Global Weather Central, is centralized within the continental United States in accordance with the Air Force command structure, and locates a larger fraction of its meteorological personnel near to the large computing machinery center than does the Navy.

The AFGWC produces products in the form needed by the ultimate Air Force and Army users and in doing this many problems are worked out in real-time. One result of the real-time operation is reduced Central Processor Unit (CPU) utilization.

One-quarter to one-half of the effort at Air Force Global Weather Central is in highly classified projects. One tenth of the pre-1971 effort is in the production of data fields which are similar to fields produced at Fleet Numerical Weather Central in Monterey.

The equipment of the Air Force Global Weather Central is not presently optimally balanced between central processor unit (CPU) power and memory capacity. Efforts to improve the balance which are being made are expected to increase CPU usage from about 50% to about 80% representing a doubling of the useful output. The current demands are overloading the existing computer capacity. Satisfaction of current demands can be improved by a factor of two by increasing computer utilization. In addition, more capacity for arithmetic and memory is required than is presently available.

As in the case of the FNWC, the AWN data base is dependent on the cooperation of foreign nations through the World Meteorological Organization. The AFGWC is processing input data from civilian satellites.

Comparison

Table 1 compares FNWC and AFGWC computer operations in late 1970. The duplication of effort in the analyses and prognoses of tropospheric data (not explicit in Table 1), which amounts to less than 17% of the total computer capacity at the FNWC and less than 10% of the total computer capacity at the AFGWC, is required for responsiveness to Service applications. This corresponds to 0.003 of DoD environmental service support system costs. The small duplication is the deliberate result of the policy of the two weather services, where possible, to exchange computer products and data and to make common use of capabilities such as the AWN.

If the decision regarding collocation/consolidation were to be made based solely on current activities, the cost involved in this duplication of effort must be compared to the cost of moving equipment and personnel. The approximate cost of this duplication of effort is estimated to be $500,000 per year. The current one-time cost of consolidation has been estimated to be $6 million--this includes the cost of moving people and equipment, the temporary lease of machines for two years to ensure continued service, and the cost of duplicate staffs during transition.

Consolidation is not an attractive option, if the decision is based solely on cost savings that could be realized by the elimination of current duplication.

Far more important to the issues of this study than current operation, however, are estimates of future environmental support requirements. These are the unmet military needs that will drive future requirements for equipment, affect change, and influence the decision with regard to collocation/consolidation of the environmental computer centers.

TECHNOLOGICAL FORECASTING

Future needs may be estimated by several different methods of technological forecasting. Linear extrapolation to project future expansion has in the past proved to be a totally inadequate method of technological forecasting. Exponential extrapolation, on the other hand, leads to widely variable estimates depending upon the

TABLE 1. ESTIMATED EFFORT ALLOCATION AT FNWC AND AFGWC
(On the basis of 1 microsecond per operation, 200 operations per term, 100% overhead)

	FNWC, Monterey, 1970 (2 CDC 6500s)			AFGWC, Offutt AFB, 1970 (4 SRU 1108s)		
	Fraction of Time or Storage	Fraction of CDC 6600	Decimal Digits per 12 Hours	Fraction of Time or Storage	Fraction of CDC 6600	Decimal Digits per 12 Hours
TROPOSPHERE						
Data Sources (Decimal digits per 12 hr)			$4.2(10)^6$			$4(10)^8$
Computer Capacity (Fraction of CDC 6600)		0.7			1.6	
Fraction Time for Data Preprocessing	0.03			0.01		
Fraction Time for Analyses	0.17 } 17% of Total Machine Capacity at FNWC			0.34 } 49% of Total Machine Capacity at AFGWC		
Fraction Time for Prognoses	0.21 }			0.15 }		
Fraction Time for Applications	0.59			0.5		
Rapid Access Storage (Decimal digits per 12 hr)			$5.1(10)^7$			$3.1(10)^8$
Fraction for Data Preprocessing	0.004			0.005		
Fraction for Analyses	0.1			0.4		
Fraction for Prognoses	0.7			0.1		
Fraction for Applications	0.2			0.5		
Slow Access Storage (Decimal digits per 12 hr)			$3.5(10)^9$			$4.7(10)^8$
Climatology Storage (Decimal digits per 12 hr)			$9.2(10)^4$			$1.8(10)^6$
OCEANS						
Data Sources (Decimal digits per 12 hr)			$2.7(10)^4$			
Computer Capacity (Fraction of CDC 6600)		0.7			0	
Fraction Time for Data Preprocessing	0.01					
Fraction Time for Analyses	0.01					
Fraction Time for Prognoses	0.001					
Fraction Time for Applications	0.98					
Rapid Access Storage (Decimal digits per 12 hr)			$4.4(10)^6$			0
Fraction for Data Preprocessing	0.04					
Fraction for Analyses	0.1					
Fraction for Prognoses	0.02					
Fraction for Applications	0.8					
Slow Access Storage (Decimal digits per 12 hr)			$3.4(10)^6$			0
Climatology Storage (Decimal digits per 12 hr)			$6.2(10)^5$			0

exponent used. In this study a third approach was utilized. First, it was recognized that the development of two new tools, i.e., the meteorological satellite and the high-speed electronic computer, represents a technological breakthrough in environmental study. The question then became: what environmental sensor systems and data reduction facilities can the Services advantageously utilize to meet recognized military needs by 1975? By "advantageously utilize" we mean that the benefits to be derived from the environmental data must clearly outweigh the cost of obtaining and processing those data. It is not the purpose of this study to make cost/benefit analyses. We have, however, attempted to forecast the future burden to be placed on the Air Force and Navy environmental computer centers, if the stated needs are to be met.

DOD NEEDS FOR ENVIRONMENTAL SERVICES

The primary conclusions to be reached from a survey of DoD needs for environmental data are that many stated military needs are not now being met, or are at present only being partially met. This is due in a large part to past technological limitations in data gathering and data processing systems. Table 2 lists a few of the stated military needs for environmental data.

With the advent of meteorological satellites, sophisticated buoy systems, and high-speed electronic computers, potential capabilities for environmental data gathering and processing will have been greatly expanded. This expanded potential together with the potential capabilities of the next generation of electronic data processing equipment must be considered in light of unmet needs in arriving at a realistic estimate of future computational support requirements.

The military needs that are the bases of this study are documented in Appendix A. Meeting these military needs in 1975 would required a total computer capacity of at least 18,000 bits per microsecond. This is equal to approximately 125 CDC 6600's or more than four computers of the capability of the CDC STAR, Burroughs ILLIAC IV, Texas Instruments ASC-4X and possibly others.

TABLE 2. DOD NEEDS FOR ENVIRONMENTAL DATA

	NEEDS FOR TROPOSPHERIC DATA
• ICBM Targeting	Variations of Wind and Density Affect Precision Targeting of ICBM
• TAC Bombing	Inaccuracy of Weather Forecast Can Double or Triple Time for 14 Day, 1000 Sortie, Bare-Base Mission
• SAC, MAC, TAC, NAVAIR	Aircraft Routing; Contrail Prediction; Cloud Cover Prediction; Turbulence Prediction; Winds Aloft Prediction; Freezing Level Prediction
• Air Base Operations	Severe Weather Prediction
• Ships	Optimum Track Ship Routing; Cyclone Prediction; Wind-Wave and Swell Prediction
• Fallout Detection	Fallout Prediction
	NEEDS FOR OCEANIC DATA
• Weather Prediction	Sea-Air Heat Exchange Sea-State Forecast
• Ships	Sea Surface Temperature, Wind Waves, Sea Wave Prediction; Optimum Track Ship Routing; Surface and Subsurface Current Prediction
• Anti-Sub Warfare	Sound Propagation Ranges; Temperature and Density Profiles
• Pro-Sub Warfare	Sound Propagation Ranges; Temperature and Density Profiles; Subsurface Currents and Waves
	NEEDS FOR STRATO-, MESO-, AND THERMOSPHERE DATA
• Command and Control	
• C&C Systems	Reliability and Speed of Service of Communications
• General Communications	ELF, VLF and LF Communications
• Surveillance and Detection	
• OHD Radars	Propagation of HF Radio Transmission (MUF, LUF)
• SAT System 647	Propagation and Background of Ultraviolet Radiation
• AEDS	Propagation of X-Rays and Nuclear Particles
• SAFEGUARD	Propagation of Radar Affected by Electron Density Variations
• Satellite Control and Track	
• Spacetrack, SPASUR, AFSCF	Solar Electromagnetic and Particle Radiation Changes Affect Atmospheric Density Profiles, Causing Changes of Satellite Drag, Affecting Orbit Prediction

POTENTIAL DATA SOURCES

Referring to the question posed at the outset, we asked "What environmental sensor systems might the Services utilize to meet military needs in 1975?" Potential new satellite systems and potential new ocean data collection buoy systems were examined.

Satellites

Exemplar satellite systems to provide inputs to DoD environmental support systems in 1975 were postulated for the purpose of this study. The characteristics of the postulated exemplar satellites are shown in Table 3. Also shown in Table 3 is a comparison of those satellite systems now programmed for 1975 with the exemplar satellite system.

TABLE 3. EXEMPLAR SATELLITES VERSUS PROGRAMMED SATELLITES, 1975-1980

Exemplar System						Programmed for 1975			
		Orbit							
Satellite	Data Type	Inclin.	Altitude (km)	Number in Orbit	Measurement Data Rate (Bit Sec^{-1})	NASA/NOAA/DoD	Number Programmed	Fractional Capability of Exemplar Instruments*	Total Fractional Capability of Exemplar System*
A	Photographic	Polar	1100	4	1.5×10^5	NIMBUS I	No Photo After 1972	0	0
	Emission					NIMBUS D(70) NIMBUS E(73) TIROS M(70) TIROS N(75)	2	0.7	0.3
B	Absorption	Low Inc.	700	4	1.7×10^3	Not Planned	0	0	0
C	Photographic	Equat.	35,800	4	2.5×10^7	SMS/GOES/ FR/JAP	2 + 1 + 1	0.7	0.7
	Emission					None		0	0
	DCP Interr.					SMS/GOES/ FR/JAP	2 + 1 + 1	1.0	1.0
D	Solar Flux	Equat.	128,000	3	1.4	SOLRAD HI	3	1.0	1.0
E	Communications Pelay	Equat.	35,800	2	2.6×10^7	INTELSAT IV	23	1.0	0.7

*Ratio (instruments on board or in orbit/instruments of exemplar satellite).

Of the total data available from the exemplar satellite system, which is deliberately redundant to maximize global coverage, only 25 percent is intended to be processed, requiring the equivalent of 25 CDC 6600's. The programmed satellites will provide 70 percent of the coverage of the exemplar system.

The important point to note here is the data output that should be effectively used and that will be available from the programmed satellites far exceeds the current computer capacity of FNWC and AFGWC together. In other words, to take advantage of the environmental data that will be available from the NASA/NOAA/DoD programmed satellites will require a significant increase in DoD computational equipment.

Ocean Data Collection Platforms

Table 4 reviews current and projected ocean data collection platforms along with a hypothetical exemplar buoy system defined in Appendix D. The important point here is that the output from current and projected data collection platforms amounts to only 1% of an exemplar system but this 1% is enough to justify the ocean model used in this study to estimate future DoD environmental support services computer requirements. Computational requirements for the more elaborate ocean models exceed currently available computer capacity.

TABLE 4. OCEAN DATA COLLECTION PLATFORMS OF 1970 AND 1975-80

TIME	PLATFORM	NO.	INSTRUMENT*	TELEMETRY SAMPLE PERIOD (HRS)	TELEMETRY DATA RATE (BITS/SEC)
PRESENT 1970	SHIPS OF OPPORTUNITY	600 150	METEOROLOGIC SXBT	6 12	$2(10)^2$ 2
	RECCO AIRCRAFT	10 5	AXBT ART	0.5 0.1	1 2
	COASTAL STATIONS	200	METEOROLOGIC	6	5
	BUOYS	10	METEOROLOGIC OCEAN	1-6	5
PROJECTED 1975 - 80	SHIPS OF OPPORTUNITY**	1500 600	METEOROLOGIC SXBT	1 6	$5(10)^2$ $5(10)^2$
	RECCO AIRCRAFT	40	AXBT ART WAVE RECORD	0.1	$2(10)^2$
	COASTAL STATIONS	400	METEOROLOGIC	3	$2(10)^2$
	BUOYS***	35	METEOROLOGIC OCEAN	0.1-0.2	$9(10)^3$
EXEMPLAR 1975-80	BUOYS***	3500	METEOROLOGIC OCEAN	0.1-0.2	$9(10)^5$

*SXBT, SHIPS EXPERIMENTAL BATHYTHERMOGRAPH; AXBT, AIRDROPPED EXPERIMENTAL BATHYTHERMOGRAPH; ART, AUTOMATIC RECORDING THERMOGRAPH.
**PARAMETERS: STANDARD METEOROLOGICAL PLUS OCEAN TEMPERATURE, SALINITY, CURRENTS, TIDES, SEA STATE, AMBIENT NOISE.
***SATELLITE INTERROGATION AND RELAY.

DATA PROCESSING REQUIREMENTS AND CAPABILITIES

Table 5 summarizes characteristics of computers available in 1975, expressed in comparison with the CDC 6600. Computers now in use at FNWC (two CDC 6500's) approximate 1.4 the capability of a CDC 6600; those at AFGWC (four SRU 1108's) approximate 1.6 that capability.

TABLE 5. COMPUTER SPEED COMPARISONS AND COST ESTIMATES

Class	Manufacturer	Computer	Range of Ratio Normalized to CDC 6600	Ratio As Used in Report	Cost Range (In millions)	Cost Used* In Report (In millions)
1	Univac	1108	0.3 - 0.6	0.4	2 - 4	3
	Control Data	6500	0.5 - 0.8	0.7		
	Univac	1108 MP	0.5 - 0.9	0.7		
2	Control Data	6600	1	1	4 - 6	5
	Univac	1110				
3	Control Data	7600	3 - 8	5	7 - 10	8
	IBM	360/195	5 - 8			
4	Control Data	STAR	22 - 31	30	10 - 20	12
	Texas Inst.	ASC-4X	25 - 35			
	Burroughs	ILLIAC IV	27 - 38			

*Based on production quantities.

Table 6 presents a summary of the projected computer requirements and capabilities for the 1975-1980 period based upon probable military needs for the same period. Utilizing seconds of CDC 6600 operations per second of chronologic time needed for data processing as the standard measure, it can be seen that the problems to be solved require a grand total of 112.6 seconds per second. To meet these requirements with each problem having a dedicated machine of discrete capability, requires equipment with a total capacity of 166.6 seconds per second. However, as is discussed in Section V, each problem does not require full use of a dedicated machine.

TABLE 6. 1975-1980 PROJECTED COMPUTER REQUIREMENTS AND CAPABILITIES

Domain of Interest	Projected Requirement (Sec Sec^{-1})*	Total	Appropriate Computer Machine	Capacity (Sec Sec^{-1})	Total
TROPOSPHERE					
Global Primitive Eq. and Window Models	8.3		Class 4	30.0	
FNWC Applications (1970)	3.3		Class 3	5.0	
AFGWC Applications (1970)	3.3		Class 3	5.0	
Data Collection and Preanalysis for all of above					
AWN (1970 Capacity)	0.04		Class 1	0.4	
Satellite Data - Troposphere	20.3		Class 4 Dedicated	30.0	
Buoy Data - Oceans	0.2		Class 1	0.4	
Program Development	8.8				
Equipment Maintenance	11.0				
Subtotal		55.0			70.8
OCEANS					
Global Oceans Model	11.3		Class 4	30.0	
Sound Propagation Mapping	12.5		Class 4 Dedicated	30.0	
Other FNWC Applications (1970)	0.2		Class 1	0.4	
Data Collection and Preanalysis for all of above					
Buoy Data (Oceans)	0.4		Class 1 Dedicated	0.4	
Program Development	6.1				
Equipment Maintenance	7.6				
Subtotal		38.1			60.8
STRATO-MESO-THERMOSPHERE					
Global S-M-T Model	10.0		Class 4	30.0	
Radio Propagation	2.1		Class 3	5.0	
Satellite Drag	0.3				
Solar Disturbance Prediction	0.01				
Data Collection and Preanalysis for all of above					
Satellite Data S-M-T	0.04				
Program Development	3.1				
Equipment Maintenance	3.9				
Subtotal		19.5			35.0
Grand Total		112.6			166.6

*Seconds of CDC 6600 operation per second of chronologic time of needed data processing or CPU time normalized to time needed by CDC 6600.

ALTERNATIVE OPTIONS

To meet the basic objective of this Task, it is now necessary to consider the DoD alternatives involved in the possible collocation and/or consolidation of the DoD environmental services support centers. The number of alternatives available to DoD is large; however, the spectral range of possibilities may be defined in terms of four basic options, here called Options 0, 1, 2, and 3, which represent the limits of conceivable DoD actions.

Four alternatives are considered:

Option 0 is a baseline alternative wherein no change is made to either the present operations at the Fleet Numerical Weather Central Monterey, or the AFGWC at Omaha and no provision is made for meeting either presently unmet needs or 1975 needs.

Option 1 considers the possibility of a combined Navy/Air Force operation at Omaha with no expansion of capability necessary to meet either presently unmet needs or 1975 needs.

Option 2 considers separate Navy and Air Force facilities with the expanded capability necessary to meet 1975 requirements. Both centers provide the troposphere analysis required by their respective Services; ocean buoy data via satellite are received at Omaha (if Omaha is selected as the site for the satellite data processing function) and transmitted by landline to Monterey for reduction, while satellite-obtained data on the troposphere, stratosphere, mesosphere, and thermosphere are received and processed at Omaha.

Option 3 considers an inter-Service joint operation of an environmental services support center, equipped to meet 1975 requirements, located at a site not selected by the study but separate to permit interim operation of both of the present centers until the new site is fully operational.

COST ANALYSES

The bar graph shown in Fig. 1 illustrates the investment and operation costs of each of the options by year for a ten-year period. The cost of Option 0 is represented by the dotted line and remains at $11.8 million per year for a ten-year cost of $120 million. As can be seen the ten-year cost of Option 1 is $120 million, the ten-year cost of Option 2 is $310 million while the ten-year cost of Option 3 is $280 million. For each of these options, the required new equipment exists today or will exist at the time of projected installation.

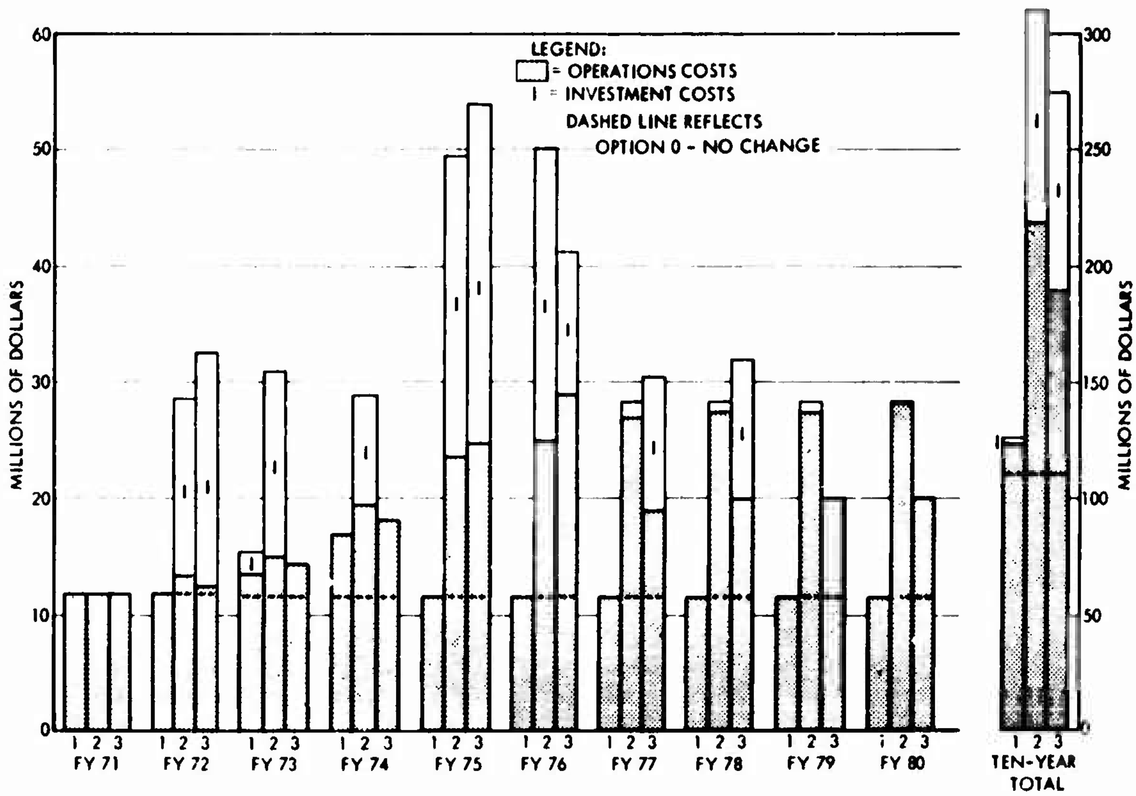

FIGURE 1. Comparison of Investment and Operating Costs for Data Processing of DoD Environmental Support Systems 1975-80 Under Options 1,2, and 3

The choice between the Option 0/1 set and the Option 2/3 set is largely a matter of cost/benefit analyses to be performed by the DoD to verify the military needs and justify the expanded environmental support capability. Given this need, verified by cost/benefit analyses, the choice then becomes either Option 2 or 3. The $30 million

cost difference between these two options is within the confidence limits of estimation and is not of sufficient distinction, by itself, to establish the choice. The non-quantifiable imponderables must be weighed to make a recommendation. Some of these are mentioned without evaluation in the following paragraphs.

CONCLUSIONS

A comparison of the options in terms of costs, schedules, and ability to meet likely demands for services leads to the following conclusions:

Option 0 is inadequate either in meeting current needs or probable future demands.

Option 1 is both inadequate in meeting current needs and involves higher costs with little payoff.

Option 2 does meet operational needs with continued 10 percent duplication of computer capacity, but imposes more difficult transition in development of models for Class 4 machines. The key management problem involved in Option 2 concerns the satellite data processing function, which must be responsive to the needs of both Services. Option 2, on the other hand, does provide 23 percent more reserve computer capacity than Option 3. Option 2 has advantages over Option 3 in being a simpler transition in management form, less subject to controversy in site selection, and in that two centers have a greater chance of surviving in event of war or natural disaster than one.

Option 3 meets operational needs, provides for smooth transition in Class 4 computer model development, requires joint management only where Service interests are shared while ensuring maximally responsive management where Service interests differ. Option 3 invites serious problems of organization and management. If these organizational problems are successfully solved, Option 3 makes for easier coordination of future development of hardware and software. This development may be implemented in ordered stages with a smaller chance of duplication due to incompatibility of software.

RECOMMENDATIONS

It is recommended that cost/benefit analyses of the military needs for environmental data be performed to determine the extent to which improved capabilities which are forecast to be technologically available in 1975-80 should be implemented.

If, on the basis of this analysis, the currently stated military needs are to be fully met, DoD should proceed with acquisition and installation of advanced computers and of satellite readout facilities for operational environmental services support at an investment cost over the next eight years of $90 million. Differences of physical realizability and cost between Option 2 (separate centers) and Option 3 (collocated/consolidated centers) are within the confidence limits of the estimation. The choice should be made on the basis of other management considerations.

If the stated military needs are to be met, the DoD should initiate studies to:

- Determine the optimum location of new sites.
- Determine the best way of exploiting and of augmenting satellite programs of the civil sector.
- Specify and select particular computers best suited for individual and collective operations.
- Maximize survivability of the DoD automated environmental services support systems in the event of war and natural disaster. Provision of back-up capability between the two centers should also be studied.

In addition, if the stated military needs are to be met, DoD should initiate two new equipment developments:

- A greatly expanded ocean data collection system utilizing ships and buoys in recognition of a current deficiency wherein only 1 percent of the ocean data estimated to be needed in 1975 is presently programmed to be available.

- A communication relay satellite system in recognition of the political limitations of the civilian INTELSAT which is unlikely to be dedicated to future military needs for relaying environmental data either from other satellites or from buoy sources.

If Option 2 or 3 is implemented, certain cautions should be observed:

- The estimates leading to the conclusions of this report are initial approximations not to be taken as a final definitive plan.
- To the extent possible, Option 2 or 3 should be implemented in stages, testing the practicality of each step as it progresses.

I. INTRODUCTION

OBJECTIVE

It is the objective of this study to examine the feasibility of a collocation and/or consolidation of the Navy and Air Force current and programmed (five years) operational environmental services computer centers. Subtasks of this study were directed to the examination of: the needs of both Services for environmental data; the operational models and procedures utilized by the Navy and Air Force centers; the systems of data processing and communication used in connection with the missions of each of the two centers.

This Study was undertaken by the Institute for Defense Analyses for the Director of Defense Research and Engineering (Research and Technology) under ARPA Task Order T-80. The work began in May 1970.

MODUS

The methodology adopted to meet the objectives of this task involved six steps. First, the current operations at the Fleet Numerical Weather Central at Monterey and at the Air Force Global Weather Central at Omaha were examined in detail. The results of this examination are documented in Appendices B and C to this study.

Second, a collation of military needs, both current and forecasted, was made primarily to identify unmet needs. This effort is documented in Appendix A.

The third step involved the analysis of potential new data sources, specifically, satellite systems and ocean data collection buoy systems. Appendix D documents this analysis and gives a cost estimate of both systems to provide a realistic basis for estimating

the magnitude of possible new data source systems. A comparison is made between the data rate output possible from an optimal satellite program of satellite and ocean data collection platforms and the data rate output to be expected from satellites and data collection platforms presently programmed for 1975.

In step four, the implications of potential military needs and the potential capabilities of new data sources are related to computer requirements of 1975 computer capabilities leading to a realistic estimate of machine and personnel needs in 1975. Appendix F documents this effort. Included in Appendix F is a time plan and personnel estimate for each of the several realistic DoD alternatives for equipment organization.

Step five involved the development of cost estimates for the alternative configurations. These are described in Appendix G.

In the final step, the organizational ways of meeting 1975 requirements, the options open to DoD decision makers, are compared leading to recommendations for DoD action.

ORGANIZATION OF THIS DOCUMENT

The organization of this document in general follows a step-by-step procedure outlined above. Section II reviews current Navy and Air Force operations and identifies areas of duplication of data processing. (See Appendices B and C)

Section III discusses military needs for environmental data with the emphasis on currently unmet and future needs. (See Appendix A)

Section IV discusses potential new data sources. (See Appendix D)

Section V analyzes the computer requirements involved in meeting likely future DoD needs for environmental data. (See Appendices E and F)

Section VI reviews the possible options open to DoD. (See Appendices F and G)

Section VII presents the recommendations of this study.

II. CURRENT DOD ENVIRONMENTAL SERVICES SUPPORT SYSTEMS

In this section, the organization of the weather services which operate the DoD environmental services support computer centers is described. Following this general description, the primary centers themselves are characterized; the input data network used to provide input to the computational centers is characterized and the output data network which delivers the products from the weather centrals to the users is then outlined.

ORGANIZATION OF DOD ENVIRONMENTAL SERVICES SUPPORT SYSTEMS

Support Costs, 1971

The cost and manpower allocation for the entire DoD effort for environmental services support in fiscal year 1971 is outlined in Table 7. The total allocation is $243 million and 16,623 people. The National budget for meteorological services is $410 million. DoD's portion of the National budget is 53% of the funds and 53% of the manpower allocated. Of these activities, the weather centrals, the primary centers, derive $8 million from the Air Force and $6 million from the Navy. Because of organizational differences, it is difficult to relate these data from the Federal Plan for Meteorological Services to the budgets of several DoD centers. It is significant, however, to point out the proportionate fraction of the total budgets which are spent in carrying forward the primary centers which are the location of large-scale computational machinery.

Weather Services

The chief emphasis of the Air Weather Service in operating AFGWC is to provide services with respect to the troposphere and lower

TABLE 7. SUMMARY OF U.S. FUNDING AND MANNING FOR ENVIRONMENTAL SERVICES SUPPORT ACTIVITIES IN FY 1971[a]

	FUNDING (in millions of dollars)						MAN YEARS					
	METEOR. SERV. SUPPORT ACT.				MEP[c]	TOTAL	METEOR. SERV. SUPPORT ACT.				MEP	TOTAL
OPERATIONS	ARMY	AIR FORCE	NAVY[b]	TOTAL			ARMY	AIR FORCE	NAVY	TOTAL		
Observations	$ 9	$ 59	$11	$ 79	$ 9	$ 88	1,023	3,134	613	4,770	390	5,160
Upper Air		(4)	(.5)									
Upper Air Rockets		(3)										
Surface Observ.		(9)	(4)									
Weather Reconn.		(42)	(4)									
Weather Radar		(.3)	(1)									
Subsurface Obsv.					(4)							
Op.Met.Sat.Obsv.		(.3)	(1)									
Air-Sea Interact. Zone					(4)							
Upper Air Zone Obs.					(1)							
Analyses & Forecasts		16	8	24	5	29 [d]		1,325	713	2,038	354	2,392
Primary Centers		(8)	(3)	(11)	(3)	(14)						
Area & Guid.Centers		(3)	(5)		(2)							
Specialized Centers		(5)										
Communications		24	4	28	2	30		111	238	349	195	544
High Speed Teletype		(17)	(3)		(1)							
Facsimile		(7)	(1)		(1)							
Dissemination to Users		32	3	35	2	37		2,928	357	3,285	223	3,508
Weather Service Offices		(30)	(1.6)		(1.6)							
Flt.Service Stations			(.7)									
Coastal Warning Display			(.5)		(.3)							
Studies & Consultants		(1.6)	(.1)		(.2)							
Voice		(.1)	(.2)		(.1)							
TV		(.1)	(.1)		(.1)							
General Agency Support	1	37	15	53	6	59	131	3,303[e]	975	4,409	610	5,019
Operations Totals by Service	$10	$168	$41	$219	$24	$243	1,154	10,801	2,896	14,851	1,772	16,623
Other Ops in DOD					6	6				75		
Total DOD Operations				219	30	249[f]						
All Other Agencies (FAA, Commerce,etc.)				191	26	217				9,862		
Total U.S. Envir. Service Ops.				410	56	466				24,713		
SUPPORTING RESEARCH												
DOD				14	12	26						
All Other Agencies				63	59	122						
Total U.S. Envir. Service Research				77	71	148						
TOTAL U.S. OPERATIONS & RESEARCH FUNDING (for Envir. Serv. Activities)				$487	$127	$614						

(a) This summary reflects data abstracted from the FY 1972 issues of two Federal Plans: (1) The Federal Plan For Meteorological Services and Supporting Research (MSSR), pp. 9, 45, and 46) and (2) The Federal Plan for Marine Environmental Prediction (MEP), p. 15.
(b) The major portion of the Navy's activities for environmental services is reported in the Federal Plan for MSSR; the remainder in the Federal Plan for MEP. Hence, to obtain total environmental service activities for N vy, add amounts in two columns (i.e., $41 + $24 million).
(c) The published Federal Plan for MEP does not identify funding and manning by Service as shown here but the Navy's portion was obtained from the Navy's report to the Federal Coordinator.
(d) Parentheses indicate component contributions to totals. The dashed line enclosing funds for Primary Centers highlights the general area covered by this study.
(e) The 3303 man years reported for the Air Force include some non-AF manning used for MSSR activities in the Air Force.
(f) Total DOD funding for Environmental service activities operations constitutes 53 percent of the total U.S. spending for such services (i.e., $249 out of $466 million).

stratosphere, with especial consideration of the boundary layer over terrain north of 20°N and of providing automated real-time response to queries. Some attention is given to the space environment; about half the present capacity is dedicated to projects of high military security classification.

The chief emphasis of the Naval Weather Service is on the marine environment, both tropospheric and oceanic, of the Northern Hemisphere. Computational capability is about equally divided between considerations of the troposphere and lower stratosphere and of the oceans.

The Automated Weather Network (AWN) operated by the Air Force is at present the primary input of data to the DoD computational centers. Both the Air Force Global Weather Central and the Fleet Numerical Weather Central derive data from this center which are described in Fig. 2. The Air Force also operates, in addition to AFGWC, the Environmental Technical Applications Center (ETAC) for climatic support and other studies, and the Aerospace Environmental Support Center (AESC) which does space environment support. The relative roles of these with their personnel complement are listed in Table 8.

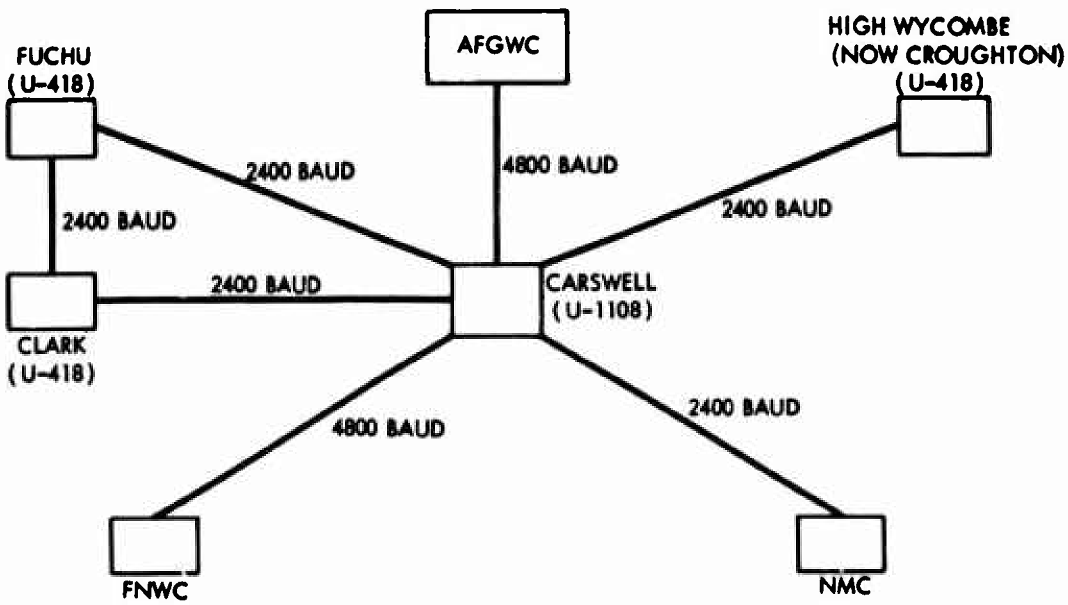

FIGURE 2. USAF Automated Weather Network

TABLE 8. AWS CENTRALIZED SUPPORT

• AFGWC - OPERATIONAL SUPPORT	492 persons
COMMAND AND CONTROL MISSION EXECUTION	
• ETAC - CLIMATIC SUPPORT, STUDIES	348
DESIGN FACTORS MISSION PLANNING	
• AESC - SESS	70
7.5% OF AWS =	910

The environmental services support systems operated by the Navy are mapped on Fig. 3. This is a more dispersed network of computers and centers consonant with the more decentralized command structure of the Navy. Fleet Numerical Weather Central Monterey is a central computer facility but substantial computational capability is maintained also at Fleet Weather Central Rota, Norfolk, Pearl Harbor, and Guam.

The organization of the Air Weather Service is described in Fig. 4. The Air Weather Service is a subordinate command of the Military Airlift Command of the U.S. Air Force. It has representative wings in every major Air Force command. A principal activity of the Air Weather Service is the Air Force Global Weather Central located at Offutt Air Force Base, Omaha, Nebraska. The Air Weather Service serves both the Air Force and the Army in environmental services support.

The Naval Weather Service is subordinate to the Chief of Naval Operations. Its headquarters are located in Washington, D.C., and it has a more decentralized system of support of Naval forces all over the world. The areas of responsibility for meteorological services and the weather centrals which accomplish that support are listed in Fig. 5. Similarly, in Fig. 6, the areas of responsibility for oceanographic services are shown. The Naval Weather Service Command support is given to the fleets from Weather Centrals at Guam, Pearl Harbor, Norfolk, and Rota, with support in some areas from Fleet Weather

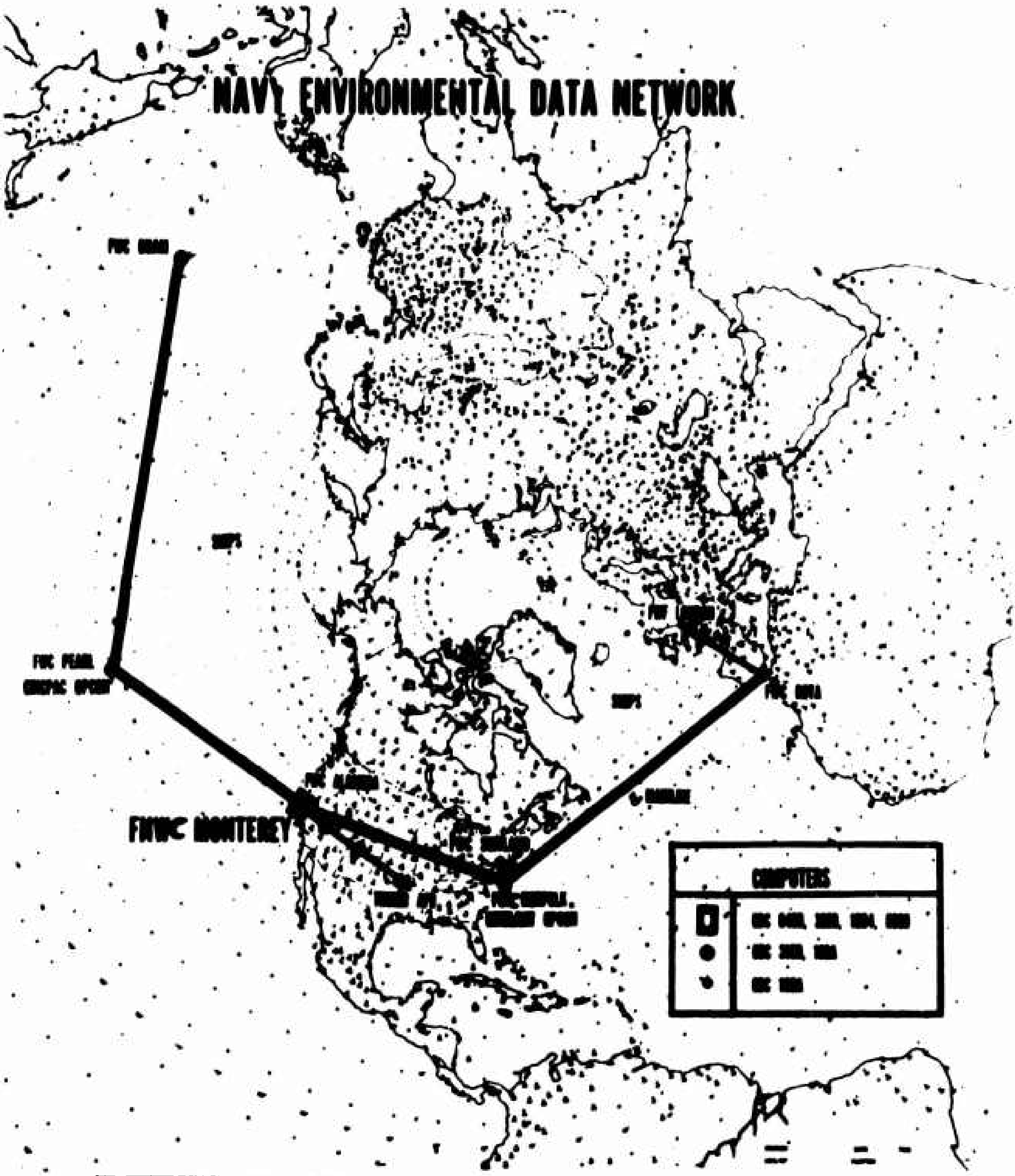

FIGURE 3. Navy Environmental Data Network

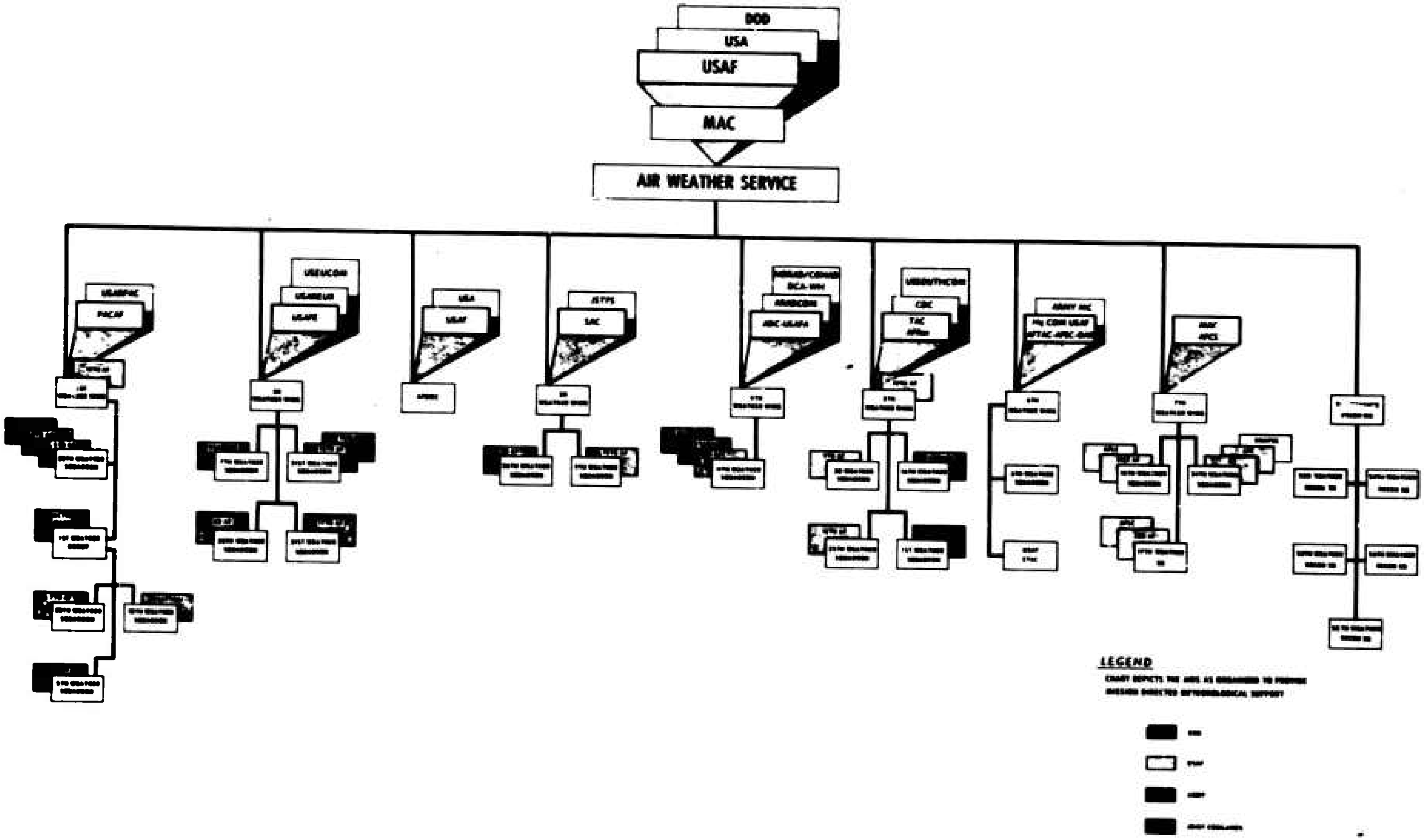

FIGURE 4. Air Weather Service Organizational Chart

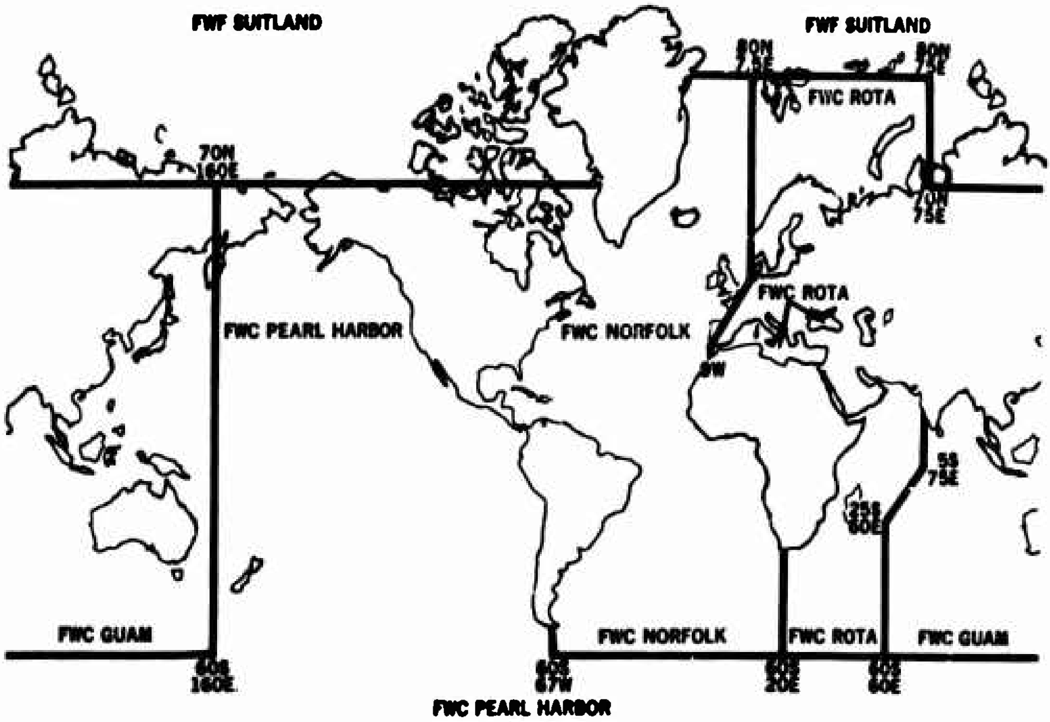

FIGURE 5. Naval Weather Service Command Areas of Responsibility for Meteorological Services

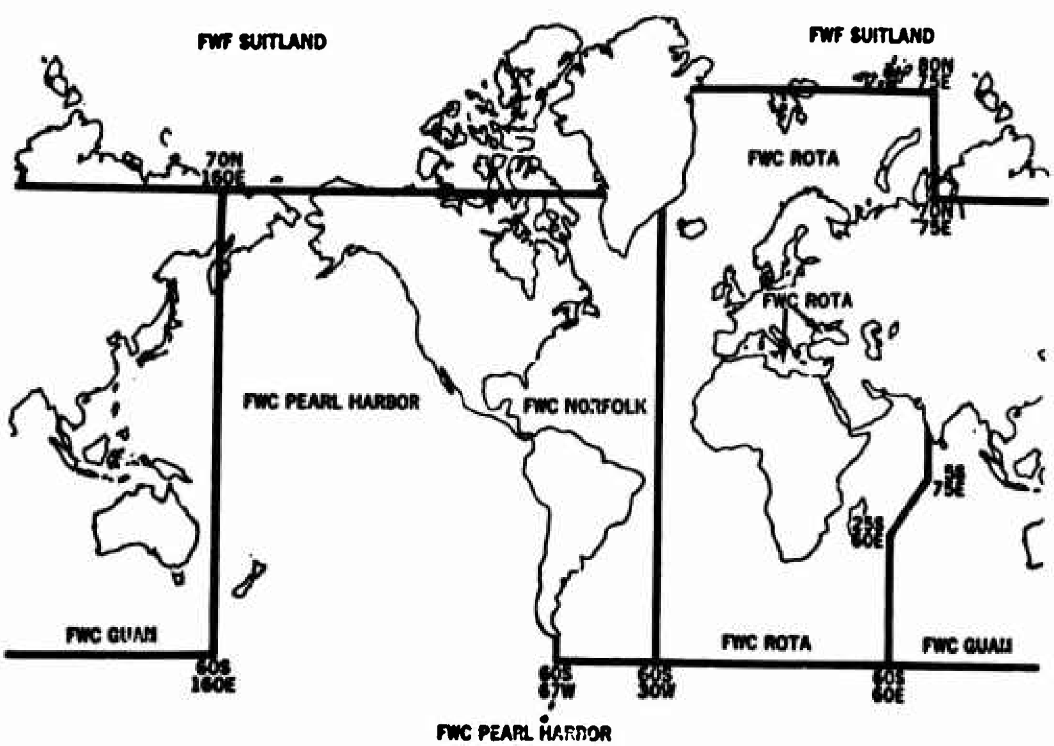

FIGURE 6. Naval Weather Service Command Areas of Responsibility for Oceanographic Services

Norfolk, and Rota, with support in some areas from Fleet Weather Service, Suitland, which is the only means the Navy has of exploiting satellite data derived from TIROS satellites.

In the Naval Weather Service system, Fleet Numerical Weather Central provides the large fields of global data to the Fleet Weather Centrals which in turn tailor the products to meet the needs of the users.

Computing Power of the Weather Services

The computing power available to the Air Weather Service expressed in millions of instructions per second (MIPS) is shown in Table 9. The primary source capacity is located at the Air Force Global Weather Central in Omaha, Nebraska. The competence at ETAC, Washington, D.C. and Asheville is directed primarily to climatology and the competence at Carswell, Clark, Fuchu, and High Wycombe (now Croughton) is used for communications of meteorological data.

TABLE 9. AIR WEATHER SERVICE COMPUTING POWER, 1970

	PROBLEM SOLVING			AWN (AFCS)		
	Word Length (bits)	Computer	Capacity (MIPS)	Word Length (bits)	Computer	Capacity (MIPS)
AFGWC (Omaha, Nebraska)	36	1108(4)	3.0	18	U-418(2)	0.8
ETAC (Washington, D.C.)	36	7044	0.4			
	6	1401	0.01			
ASHEVILLE (North Carolina)	32	70/45	0.14			
CARSWELL AFB (Texas)				36	U-1108(2)	1.5
CLARK AFB (Philippine Islands)				18	U-418(2)	0.8
FUCHU (Japan)				18	U-418(2)	0.8
HIGH WYCOMBE (England) (now Croughton)				18	U-418(2)	0.8

The computing power available to the Naval Weather Service is listed on Table 10. Dominantly located at Fleet Numerical Weather Central, Monterey, the computational capability is also substantial at Fleet Weather Centrals Pearl Harbor, Guam, Norfolk, and Rota.

TABLE 10. NAVAL WEATHER SERVICE COMPUTING POWER, APRIL 1970

	PROBLEM SOLVING			NON-ARITHMETIC		
	Word Length (bits)	Machine	Capacity (MIPS)	Word Length (bits)	Machine	Capacity (MIPS)
FNWC	60	6500 CPU (4)	4.0	12	6500 PP (20)	10.0
	24	3200 (2)	0.6	12	8090	0.05
	48	1604 (2)	0.2	12	160A	0.05
		TOTALS	4.8		TOTALS	10.1
PEARL	24	3100 (2)	0.4	12	160A	0.05
	13	8490	0.15			
		TOTALS	0.55			
NORFOLK	24	3100	0.2	12	160A	0.05
	13	8490	0.15			
		TOTALS	0.35			
GUAM	24	3100	0.2			
	13	8490	0.15			
		TOTALS	0.35			
ROTA	24	3100	0.2			
	13	8490	0.15			
		TOTALS	0.35			
ALAMEDA, SUITLAND, AND LONDON				12	160A (3)	0.15

PRIMARY CENTERS

In describing the primary computational centers of DoD environmental services support systems, the following items are discussed in turn: computer configurations, current operations of the centers, utilization of central processor capability, and a general division of effort.

Computer Configurations

The computer configuration at Air Force Global Weather Central is described in diagrammatic form in Fig. 7. The computer system is built primarily around four Univac 1108 machines.

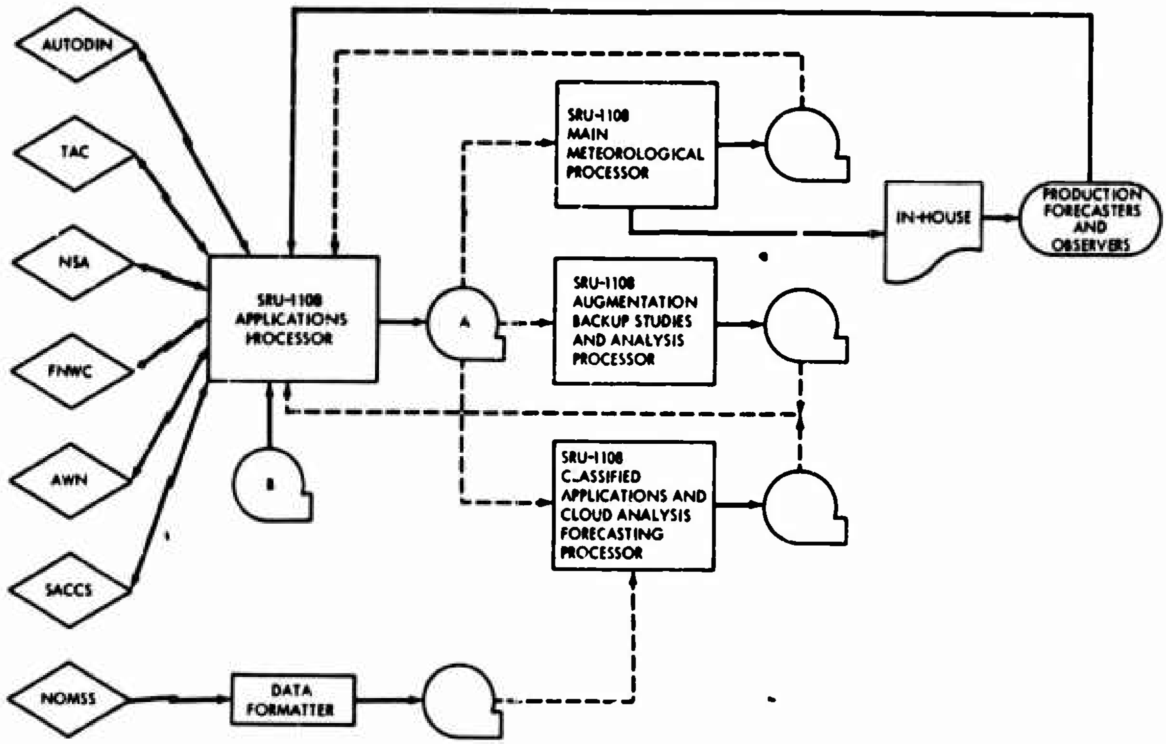

FIGURE 7. EDP Flow, AFGWC, 1970

The computer configuration at FNWC Monterey is described diagramatically to show the data processing flow in Fig. 8. This system is one which consists primarily of two CDC 6500's, two CDC 3200's, and other equipments which are used for communications relay.

Shown in Fig. 9 is the data processing flow at Fleet Weather Central, Pearl Harbor, representative of the other Fleet Weather Centrals. Fleet Weather Central, Pearl Harbor, receives basic fields from Fleet Numerical Weather Central as well as observational data which are then used to produce its output which in general goes to the tactical forces.

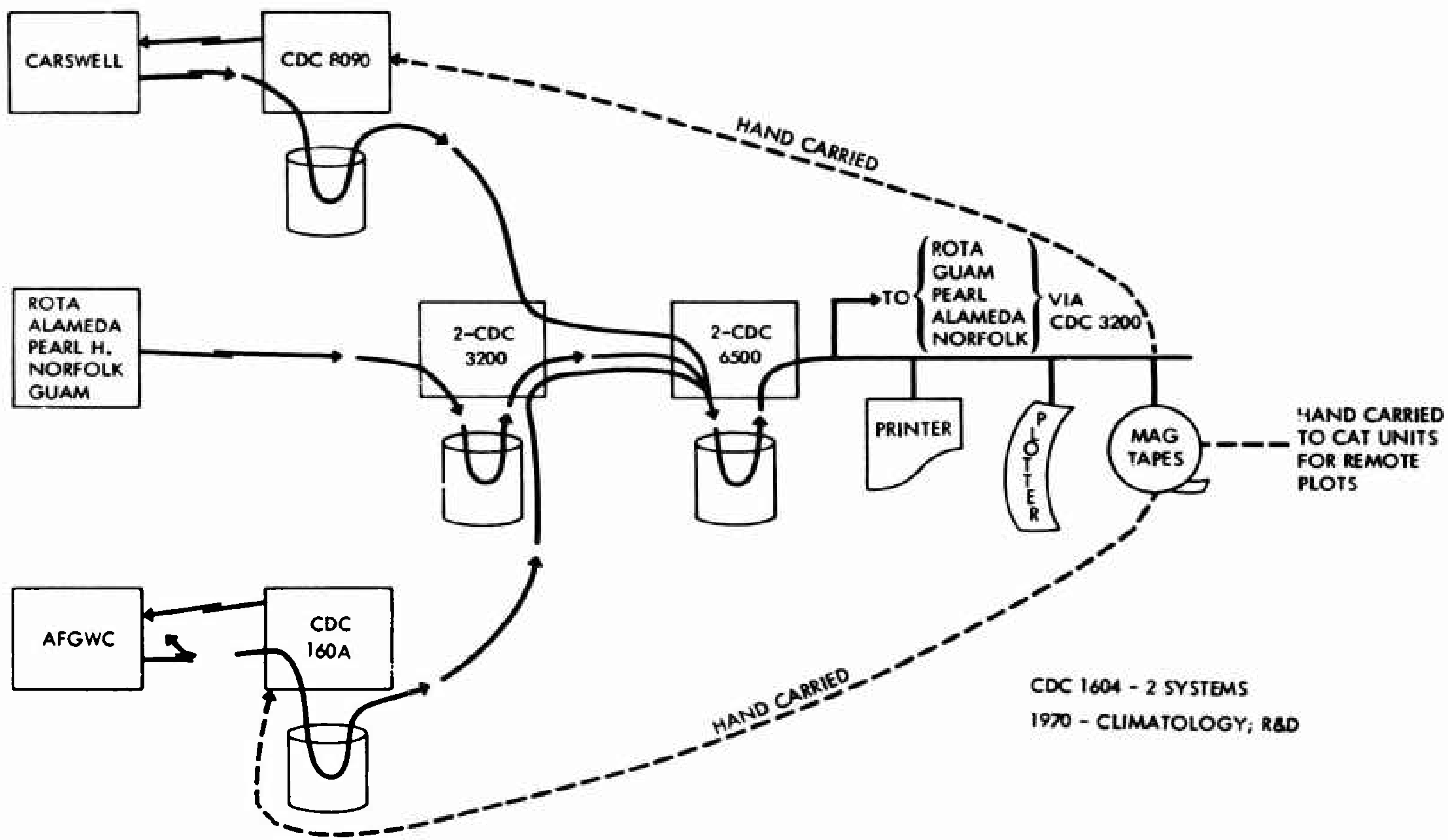

FIGURE 8. EDP Flow, 1970, FNWC Monterey

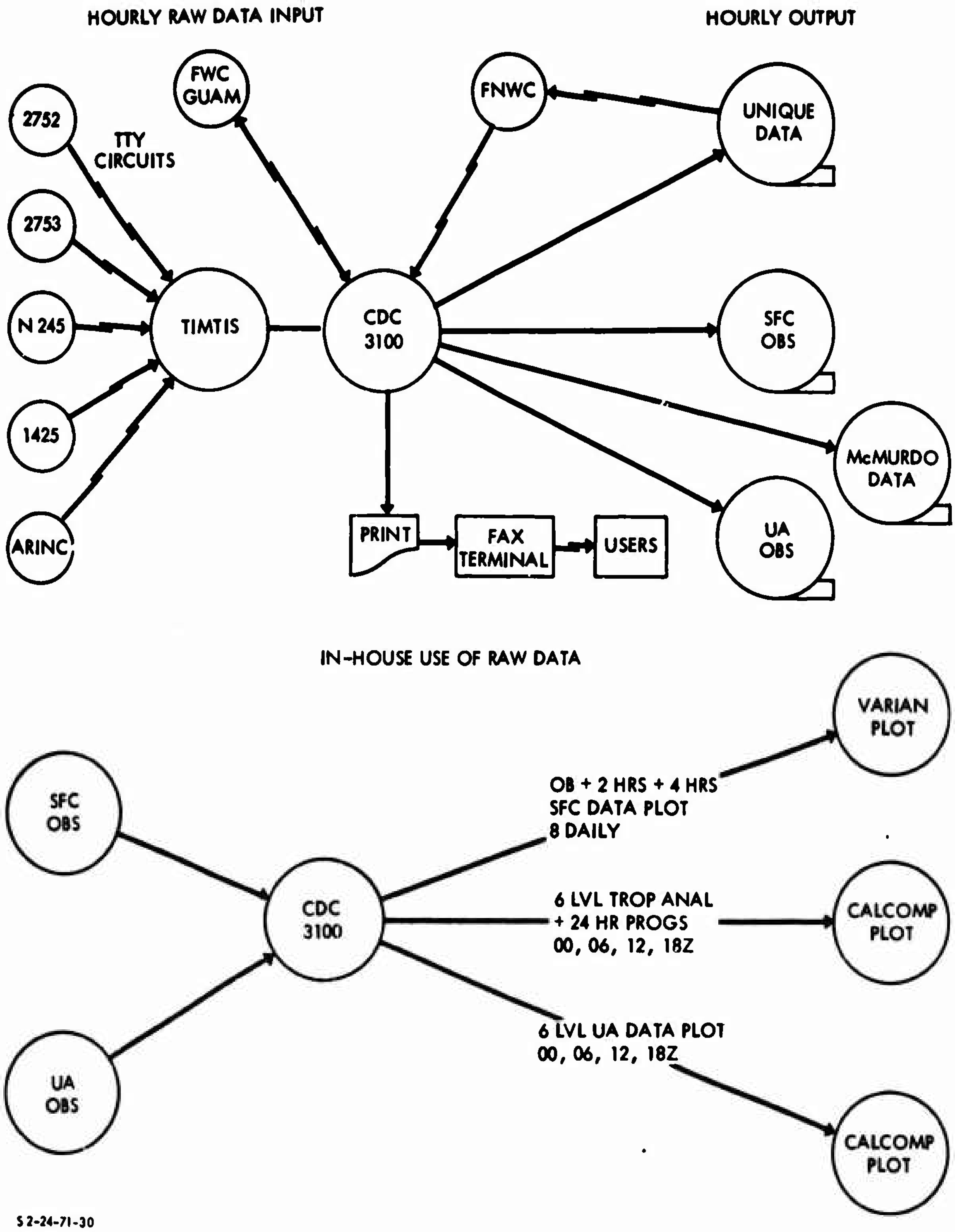

FIGURE 9. EDP Flow, FWC Pearl Harbor

Current Operations of the DoD Weather Services

The current operations of the Air Force Global Weather Central are primarily concerned with analyses, prognoses, and applications of the troposphere. These operations are described in Table 11 which is laid out in the form of the flow considered in analyses made by this study and detailed in Appendices B and C. First are considered the data sources of which there are 34. Also listed is the observed data input which is delivered to AFGWC as 122 parameters. Estimates by this study of the data rate input are 4600 bits per second. The AWN channel capacity alone is 4800 bits per second overall. The derived data input is computational program products which are used as inputs to other programs. They include such things as the results of surface pressure analyses and prognoses. There are 88 types of these with an estimated storage requirement of about 10^9 bits.

TABLE 11. 1970 OPERATIONS OF AFGWC TROPOSPHERIC ANALYSIS AND PROGNOSES AND APPLICATIONS

DATA SOURCES	OBSERVED DATA INPUT	DERIVED DATA INPUT	COMPUTER PROCESSING	TRANSMISSION OUTPUT
EXAMPLES: MERC. THERMOMETER PSYCHROMETER BAROMETER TEMPERATURE RAOBS (34 TYPES)	EXAMPLES: SURFACE PRESSURE SURFACE TEMPERATURE HEIGHT OF 1000 MB WIND SPEED ALOFT (122 PARAMETERS)	EXAMPLES: SFC PRESS. ANAL. SFC TEMP. ANAL. 1000 MB HEIGHT ANAL. SFC PRESS PROG (88 TYPES)	EXAMPLES: SFC PRESS. ANAL. 00Z, 06Z, 12Z, 18Z UPPER AIR ANAL. 00Z, 06Z, 12Z, 18Z STRATOSPH. ANAL. (53 PROGRAMS)	EXAMPLES: AWN DCT HSP AUTODIN DEDICATED CIRCUITS FACSIMILE
	ESTIMATED DATA RATE IN: ($4.6(10)^3$ BITS/SEC)	ESTIMATED STORAGE REQUIREMENT: ($2.9(10)^8$ BITS)	ESTIMATED NO. STORAGE IN PROC. ($5.2(10)^9$ BITS) COMP. PROC. TIME PER 12 HOURS OF 4-1108 6 HOURS PLUS APPROX. 6 HOURS FOR HIGHLY CLASSIFIED DATA PROJECTS	ESTIMATED TRANSMISSION RATE: 1552 BITS/SEC^{-1} OUT 5900 BITS/SEC^{-1} IN
	ACTUAL AWN CAPACITY 2400-4800 BITS/SEC	ACTUAL $1.6(10)^9$ BITS FOR 36 HOURS OF DATA BASE	ACTUAL AFGWC OP. SCHED. FOR 4 U-1108 4 HOURS IN 12 FOR NOT HIGHLY CLASSIFIED PLUS 4 HOURS IN 12 FOR HIGHLY CLASSIFIED PROJECT	TRANSMISSION RATE 10,950 BITS/SEC^{-1} OUT $1.5(10)^6$ BITS/SEC^{-1} IN

In the fourth column of Table 11 are listed the computer process estimates. Examples of the 53 programs which have been taken into account are the surface pressure analysis and the upper air analysis. The estimate of data items in storage in the processing is about 10^9. The computer processing time for 12 hours of four U-1108 operations is about equally divided between the highly classified data projects not detailed here and the unclassified weather projects. The actual operation schedule accounts for 4 hours and 12 hours for each of these types of activity, respectively. The output transmissions, by a variety of means such as the Automated Weather Network, AUTODIN and others, have an estimated transmission rate of $1.5(10)^3$ bits per second out and $5.9(10)^3$ bits per second for use internally within AFGWC. The actual transmission capacity of the outgoing channels is about 11 kilobits per second.

Summarized in Table 12 are the operations of Fleet Numerical Weather Central Monterey for the purposes of tropospheric analyses, prognoses, and applications. In an arrangement similar to that previously described, there are 23 types of data sources considered, 25 types of observed data input with an estimated mean data rate input of 1620 bits per second. The derived data input has an estimate storage requirement of about 10^{10} bits. The computer processing without allowance for overhead involves about 10^{10} operations and requires storage of about 10^8 bits with a computer processing time of 5 hours plus 1 hour of duplication of the primitive equation model with the barotropic models in each 12 hours. Actually, the Fleet Numerical Weather Central operation schedule supports these estimates. The transmissions out from Fleet Numerical Weather Central involve 111 outputs with an estimated output rate of 1300 bits per second. The recorded output rate is about 2900 bits per second; 4600 bits per second is the communications in-house.

Of the computers located at Fleet Numerical Weather Central, about half the capacity is dedicated to oceanic studies. The operation of these studies is summarized in Table 13. The oceanic analyses, prognoses, and applications exploit 23 types of data sources, 25 sources of observed data input. The input data rate is essentially

TABLE 12. 1970 OPERATIONS OF FNWC MONTEREY: TROPOSPHERIC ANALYSES, PROGNOSES, AND APPLICATIONS

DATA SOURCES	OBSERVED DATA INPUT	DERIVED DATA OUTPUT	COMPUTER PROCESSING	TRANSMISSION OUTPUT	USERS
EXAMPLES: MERCURY THERMO-METER PSYCHROMETER BAROMETER TEMPERATURE RAOBS (23 TYPES)	EXAMPLES: SURFACE PRESSURE SURFACE TEMPERA-TURE HEIGHT OF 1000 MB WIND SPEED ALOFT (25 TYPES)	EXAMPLES: SURFACE PRESSURE ANALYSES SURFACE TEMPERATURE ANALYSES 1000 MB HEIGHT ANALYSES SURFACE PRESSURE PROGNOSES (65 TYPES)	EXAMPLES: SURFACE PRESSURE ANALYSES 00Z, 06Z, 12Z, 18Z UPPER AIR ANALYSES (50 PROGRAMS)	EXAMPLES: PRESSURE HEIGHT ANALYSES TEMPERATURE PRESSURE ANALYSES 500 MB PROGNOSES (111 OUTPUTS)	POLARIS & POSEIDON NAVAIR CARRIERS AIR BASES SHIP OPS ASW
	ESTIMATED MEAN DATA RATE IN 1620 BITS SEC^{-1}	ESTIMATED STORAGE REQUIREMENT $1.15(10)^{10}$ BITS	ESTIMATED NUMBER COMPUTER OPERATIONS (NO OVERHEAD) $8.87(10)^{9}$ STORAGE IN PROC. $1.68(10)^{8}$ BITS COMP. PROC. TIME PER 12 HOURS 5 HOURS (+ 1 HOURS PE MODEL DUPLICA-TION)	ESTIMATED TRANS. RATE OUT (NO O'HD, BAND INDEXING) 1300 BITS SEC^{-1} ESTIMATED	
	ACTUAL AWN CAPACITY 2400–4800 BITS SEC^{-1} AWN TRAFFIC 1650 BITS SEC^{-1}		ACTUAL FNWC OPERATING SCHEDULE 5 HOURS IN 12 (+1 HOURS PE MODEL DUPLICATION)	ACTUAL $2.9(10)^3$ BITS SEC^{-1} OUT $4.6(10)^3$ BITS SEC^{-1} IN-HOUSE $7.5(10)^3$ BITS SEC^{-1} TOTAL	

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TABLE 13. CURRENT OPERATIONS OF FNWC MONTEREY
OCEANIC ANALYSES, PROGNOSES, APPLICATIONS, 1970

DATA SOURCES	OBSERVED DATA INPUT	DERIVED DATA INPUT	COMPUTER PROCESSING	TRANSMISSION OUTPUT	USERS
EXAMPLES: THERMOMETER BATHYTHERMOGRAPH (23 TYPES)	EXAMPLES: SEA SURFACE TEMPERATURE WIND-WAVE HEIGHT (25 TYPES)	EXAMPLES: SEA SURFACE TEMPERATURE ANALYSES DEPTH ANALYSES & PROGNOSES (32 TYPES)	EXAMPLES: WIND-WAVE ANALYSES & PROGNOSES SOUND RAY TRACING (16 OCEANIC, 3 RAY TRACE PROGNOSES)	EXAMPLES: POTENTIAL MIXING LAYER DEPTH ANALYSES BOTTOM OF THERMOCLINE (31 OCEANIC & REQUESTED SOUND PROP. MESSAGES)	ANTI-SUB WARFARE PRO-SUBMARINE SHIP ROUTING PORT MANAGEMENT
	ESTIMATED DATA RATE INPUT 1620 BITS SEC^{-1} (SAME AS FOR ATMOSPHERE)	ESTIMATED STORAGE REQUIREMENT $1.12(10)^7$ BITS	ESTIMATED NO. COMP. OPERATIONS $3.2(10)^8$ OCEANIC $(10)^9$ EA. RAY TRACE AT 15 PER DAY STORAGE & PROCESSING $1.4(10)^7$ BITS OCEANIC $6.6(10)^5$ BITS EA. RAY TRACE COMPUTER PROCESSING TIME FOR 12 HOURS 2 MIN. OCEANIC 174 MIN. RAY TR. AT 0.17 MIN MI^{-1}	ESTIMATED TRANS. RATE OUTPUT (NO O'HD OR BAND INDEXING) 63 BITS SEC^{-1} OCEANIC $6.6(10)^5$ BITS EA. RAY TRACE	
			ACTUAL 2 HR IN 12 RAY TRACE RP-70 AT 0.17 MIN MI^{-1} $8.35(10)^5$ BITS	ACTUAL SONAR PREDICTIONS 75 BITS SEC^{-1}	

the same as for the atmosphere. The derived data input is derived in 32 types involving about 10^7 bits of storage. The computer processing involves programs such as wind-wave analyses and prognoses and sound ray tracing. The estimated number of computer operations is about 10^8 for the oceanic state variables and about 10^9 for each individual ray trace which are accomplished upon request, about 15 per day. The storage in processing involves about 10^7 bits of oceanic state variables and about 10^6 for each ray trace. The computer processing time in a 12-hour period is about 2 minutes for computation of the oceanic variables and about 174 minutes for 15 ray traces at 0.17 minutes per mile. The records of performance approximate the estimates. The transmission output is in the form of messages which describe potential mixing layer depth analyses and prognoses, bottom of the thermocline and 29 others, as well as requested sound propagation messages. The estimated transmission rate of output, without allowance for overhead or band indexing, is about 63 bits per second for oceanic state variables and about 10^6 bits for each ray trace. The traffic records show that the messages involve about 75 bits per second.

As has been described above, the Fleet Weather Centrals of which Fleet Weather Central Pearl Harbor is the example described in Table 14, are established to tailor products to meet the specific needs of the user. The allocation of time of the CDC 3100 equipments at Fleet Weather Central Pearl Harbor, and of the schedule for routine messages which transmit the output are detailed in Table 14.

The present DoD activity in the stratosphere-mesosphere-thermosphere is small. The Air Force operates the space environment support system involving ground observations of solar and ionospheric effects. It also exploits data derived in measurement of the solar flux by the VELA satellite, reporting, analyzing, and predicting solar activity and significant disturbances of the aerospace environment using both ground-based and satellite data. The purposes of these activities are to manage radio frequencies used for communications and to predict

TABLE 14. FWC PEARL HARBOR COMPUTER SYSTEMS OPERATIONS - 12 HOURS

TIME	8440 INCOMING	PROCESS 3100A	PROCESS 3100B	OUTGOING NEDN FAX	NEDN TIELINE	8490 NEDN FNWC	8490 NEDN GUAM	160A TTY PUNCH FAA 1425	KODIAK	FAA 3105	MIDWAY	FLEET BATT	WRC KUNIA	AUTODIN	FLEET FAX
0330	SPOT AIRED SPOT 6	DP	00Z TROP					AIREP					AIREP	TYRACK*	CURSTRM
0400															HAWSST 36HR FL SST
0430	SPOT 7 OOZ PS/SST			00Z SFC	PLOTREP										
0500	UA ANAL ASIA	DP					00Z COMN 00Z TROP	AIREP					AIREP		00Z SFC
0530	BARO SLP SPOT 8			00Z ANAL	FXPA					TOWBFO					
0600	ML W O	DP				FXPA		AIREP		FXPA AUPA	FXPA	AUPA	AIREP FXPA AUPA	BALW	
0630	A27, A28 SPOT 9	DP		WP 850				AIREP	BARO	AUPA/NPM	AUPA/NPM	AUPA/NPM	AUPA/NPM AIREP		
0700	HWD SPOT 10	NEWS			DITCH	AIREP				FUPA DITCH	DITCH	FUPA	DITCH	DITCH LANGLEY	850MB
0730	FCTR SPOT 11			00Z PROG		DITCH			ML						300MB
0800	06Z PREAN SPOT 12	DP TELEPLOT						AIREP	DITCH RADFO	W/O RADFO			AIREP	FBAWX	250MB
0830	ASRAP SPOT 13		R&D												200MB 400MB12
0900					PAC PLOT									NEWS	500MB12 700MB12
0930	GUAM DATA SPOT AIREP SPOT 14	DP	06Z TROP												
1000								AIREP					AIREP		500MB48 200MB24
1030	SHARPS* 06Z PS SPOT 15	DP		06Z SFC	PLOTREP										
1100	ASIA HVT						06Z TROP	AIREP					AIREP		250MB24 06Z HWSFC 06Z SFC
1130	SPOT 16	DP		06Z ANAL	FXPA ASRAP			AIREP	ASRAP	TOWBFO AUPA FXPA			AIREP		300MB 24 400MB 24
1200	SPOT AIREP		R&D MAINT			FXPA					FXPA		FXPA		
1230	SPOT 1	DP		06Z PROG				AIREP		AUPA/NPM	AUPA/NPM	AUPA AUPA/NPM	AUPA AUPA/NMP AIREP		500MB 24 700MB 24
1300					DITCH	AIREP									HWD(E)
1330	SPOT 2														HWD(W) SFC 24
1400	SPOT 3 12Z PREAN	DP TELEPLOT				BATHY		AIREP					AIREP	BATHY	00Z SFC
1430	SPOT 4 SPOT 5 FOCCPAC														SFC 36 500MB AN
1500	GUAM DATA														

*MIDWATCH ONLY AS REQUESTED BY FWC ALAMEDA

density variations which affect the ephemerides of satellites. The Navy has for a number of years operated a series of satellites for observing solar flux. This series is called the SOLRAD series; currently, SOLRAD 10 is flying and SOLRAD 11 is expected in 1972 to be a big step forward.

The operations of AFGWC in treating stratosphere-mesosphere-thermosphere data are summarized in Table 15. Nineteen types of data sources are used, mostly ground-based, deriving 10 types of observational data including neutron counts, X-ray flux. The estimated data rate input to AFGWC is about 8 bits per second. The derived data input, of which examples are radio maps, neutron count, average solar wind velocities, is limited. At present, one type is used, but 42 types are expected to be exploited before December 1971. The estimated storage requirement is at present 10^5 bits, but it is expected to increase by 2 orders of magnitude before the end of the year. The computer processing involves proton propagation prediction, radio propagation predictions. There are currently 2 programs which are expected be expanded to 32 before December 1971. The estimated storage in processing is currently 10^7 bits. The computer processing time for 12 hours of Univac 1108 is 2 minutes, expected to be expanded to 1 hour. The data transmitted out are solar maps, solar summaries, and radio predictions. The data currently go out at about 1 bit per second and expected to increase by the year's end to 19 bits per second.

Central Processor Utilization

Central processor utilization at Air Force Global Weather Central in mid-1970, as described in Table 16, expends about 9.8 processor hours per day on production of the data base, 15.3 processor hours per day for operational applications, 1.5 processor hours per day for real-time support, and 16.2 hours per day are spent in the use of the executive routine and in communications: a total of 42.8 hours per day of a theoretical maximum for four processors of 96 processor hours a day. With the addition of 2.3 hours per day for

program development, total utilization is 48% of the theoretical maximum. The low efficiency appears to be the result of two problems: the difficulties of adjusting to the real-time query-response capability of the Univac equipment and (to the change in software at the time of the initial transition from IBM to Univac equipment) an imbalance between computer processing capability and core storage. The imbalance is currently being rectified. It is expected that the utilization of the computer processor by the end of the calendar year 1971 may be up to 80%.

TABLE 15. 1970 OPERATIONS OF AFGWC IN THE STRATO-, MESO-, AND THERMOSPHERE

DATA SOURCES	OBSERVED DATA INPUT	DERIVED DATA INPUT	COMPUTER PROCESSING	TRANSMISSION OUTPUT
EXAMPLES: OPTICAL TELESCOPE NEUTRON MONITOR SAT. X-RAY DETECTOR MAGNETOMETER (10 TYPES)	EXAMPLES: NEUTRON COUNTS X-RAY FLUX MAGNETIC FIELD STRENGTH (10 TYPES)	EXAMPLES: RADIO MAPS NEUTRON COUNT AVERAGE SOLAR WIND VELOCITY (1 TYPE) (42 TYPES)*	EXAMPLES: PHOTON PROPAGATION PREDICTIONS RADIO PROPAGATION PREDICTIONS (2 PROGRAMS) (32 PROGRAMS)*	EXAMPLES: SUN MAPS SOLAR REGION SUMMARY RADIO PREDICTIONS
	ESTIMATED DATA RATE IN: (8 BITS/SEC) ($1.7(10)^3$ BITS/SEC)*	ESTIMATED STORAGE REQUIREMENTS: ($2.3(10)^5$ BITS) ($4.0(10)^7$ BITS)	ESTIMATED NO. STORAGE IN PROC. $5.0(10)^7$ BITS COMP. PROC. TIME PER 12 HR OF U1108 2 MIN (1 HOUR)*	ESTIMATED TRANS. RATE OUT: 1 BIT/SEC (10 BITS/SEC)*
	ACTUAL DATA RATE IN: AWN CAPACITY (DEDICATED CIRCUIT STC PLUS AWN)*	ACTUAL DATA RATE IN: AWN CAPACITY (DEDICATED CIRCUIT STC PLUS AWN)*		ACTUAL TRANS. RATE OUT: AWN (DEDICATED CIRCUIT STC PLUS AWN)*

*PROJECTED OPERATIONAL FOR DEC 1971

Processor utilization at Fleet Numerical Weather Central is tabulated in Table 17. Fleet Numerical Weather Central acknowledges that 2.3 processor hours per day are spent for automatic data processing. Thirty-four data processor hours per day are spent for analyses, prognoses, and operational applications; 8.3 hours per day are spent for development of new programs, and about 30.9 hours per day on special studies; a total of 75.5 CPU hours per day of the theoretical maximum for four processing units of 96. This represents 79% of theoretical capacity.

TABLE 16. AFGWC CPU EFFORT ALLOCATION

31 December 1970

FUNCTION	(HR/DAY) NOW 1970	(HR/DAY) WITH BALANCE 1971
DATA BASE PRODUCTION	9.8	15.8
OPERATIONAL APPLICATIONS		
Forecaster Aids	9.4	12.6
Mission-Tailored Forecasts	5.9	17.2
Real-Time Support	1.5	8.0
EXECUTIVE ROUTINE & COMMUNICATIONS	16.2	17.2
Subtotal	42.8	70.8
PROGRAM DEVELOPMENT	3.3	6.0
TOTAL	46.1	76.8
	(48% of 96 hours)	(80% of 96 hours)

TABLE 17. FNWC CPU EFFORT ALLOCATION

December 1970

FUNCTION	CPU HR/DAY
AUTOMATIC DATA PROCESSING	2.3
ANALYSIS	4.6
PE FORECAST (to 72 hr)	16.0
OPERATIONAL APPLICATIONS	13.4
DEVELOPMENT	8.3
SPECIAL ACOUSTIC STUDIES	28.6
GFE REIMBURSABLE (OUTSIDE)	2.3
TOTAL	75.5
Percent of theoretical capacity	(79% of 96 hours)

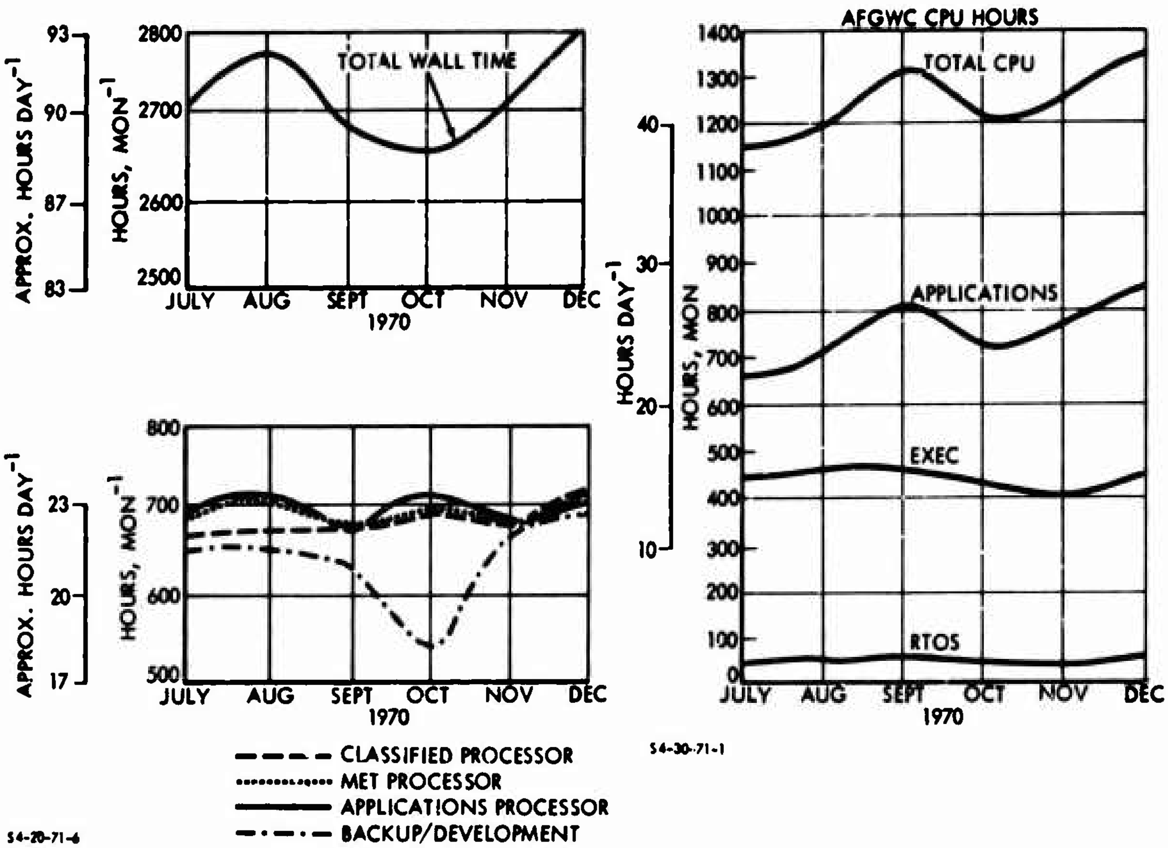


FIGURE 10. AFGWC (Wall) System Hours

In Fig. 10 is shown a plot for the period July to December 1970 of the utilization system and central processor unit at AFGWC. It should be noted that the large dip in October of the applications processor is a consequence of a five-day lay-up due to equipment failure. As a consequence of the addition of core storage and other changes to the 1970 configuration, computer utilization at AFGWC is expected by December 1971 to be greatly improved. Figure 11 shows the potential U-1108 CPU usage expected of the balanced AFGWC configuration. In this figure are the results of tests made by the computer vendor of operation of an Univac U-1108 processor coupled with a core memory of 196-kiloword capacity. With the simulated problem typical of those of AFGWC, the central processor utilization was near the theoretical maximum except in the second, third and fourth periods which show the effect of a real-time response to a route forecast query.

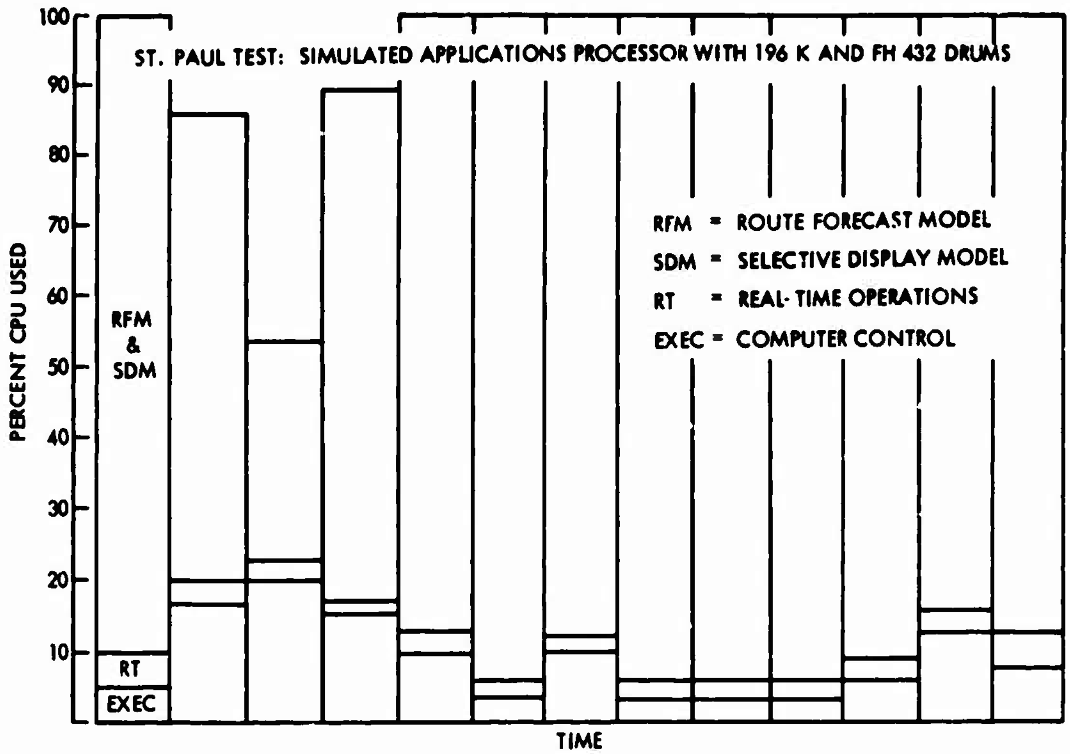


FIGURE 11. AFGWC Configuration with Balance, 1971: Potential U-1108 CPU Usage

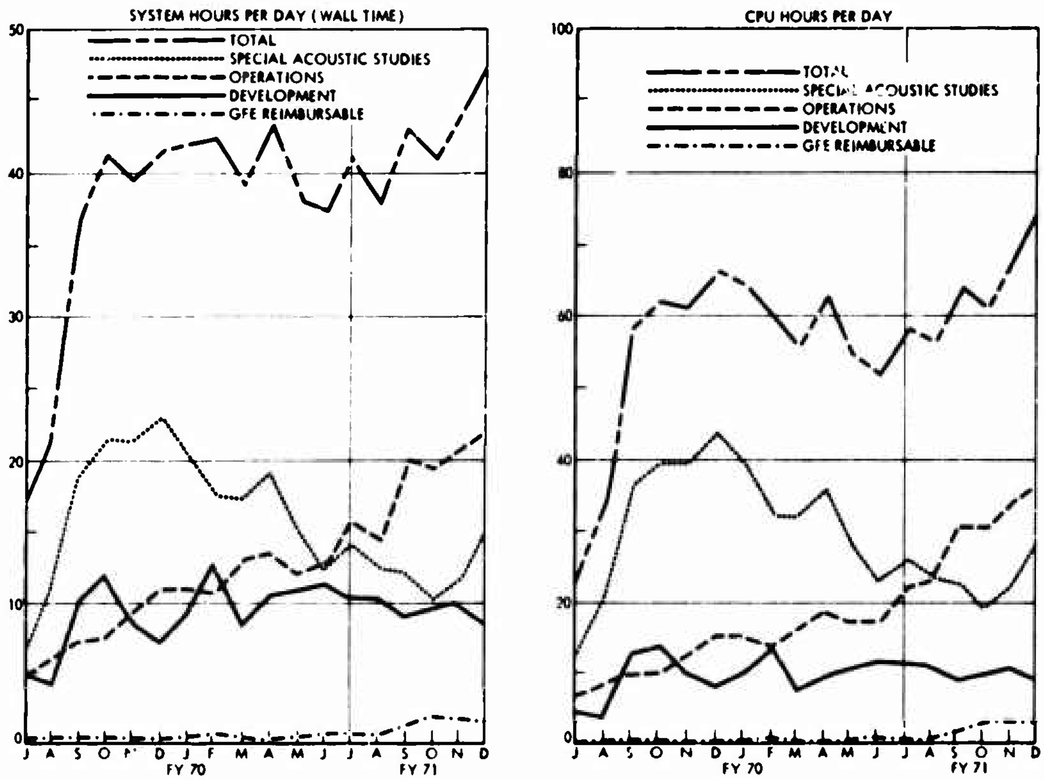


FIGURE 12. Actual FNWC System and Computer Utilization

In Fig. 12 is shown the actual FNWC system and computer utilization in 1970 for the period from July 1969 to December 1970.

Division of Effort

The division of effort allocated at Fleet Numerical Weather Central and Air Force Global Weather Central, summarized in Table 18, reflects the different emphasis of the two centers. It should be noted that the Fleet Numerical Weather Central activities are divided about equally between the studies of the troposphere and of the oceans, where the Global Weather Central in effect concentrates on the troposphere alone. Both Fleet Numerical Weather Central and Global Weather Central have equipment of comparable capability. The data sources available to Air Force Global Weather Central include a certain amount of satellite data received from the National Environmental Satellite Center at Suitland. In both cases, however, the input data are about 10^6 decimal digits per 12 hours. With computers of comparable capacity, that is, expressed in terms of CDC 6600, both centers have the equivalent of about 1.4 CDC 6600's, defined later in this report as a Class 2 computer. Half of that capacity is used at Fleet Numerical Weather Central for tropospheric studies. That half is divided between data processing analyses, prognoses, and applications in the ratio 0.03/0.17/0.21/0.59. The other half of the Fleet Numerical Weather Central's resources are concerned with about 10^4 decimal digits per 12 hours of ocean data. The bulk of that computer capacity is spent on applications. Table 18 also shows estimates for rapid access storage approximately 10^8 bits per second of decimal digits per 12 hours, slow access storage, and of archival-type storage used for climatology purposes.

The only area where there is duplication between the activities of Fleet Numerical Weather Central Monterey and Global Weather Central Offutt, is concerned with the computer effort dedicated to analyses and prognoses of the troposphere which represents 17% of the computer capacity of Fleet Numerical Weather Central. Currently 10% or less of the activity at Air Force Global Weather Central duplicates programs at FNWC Monterey. For purposes of considering the necessity for consolidation or collocation of the present systems, then one could say

TABLE 18. ESTIMATED EFFORT ALLOCATION AT FNWC AND AFGWC
(On the basis of 1 microsecond per operation, 200 operations per term, 100% overhead)

	FNWC, Monterey, 1970 (2 CDC 6500s)			AFGWC, Offutt AFB, 1970 (4 SRU 1108s)		
	Fraction of Time or Storage	Fraction of CDC 6600	Decimal Digits per 12 Hours	Fraction of Time or Storage	Fraction of CDC 6600	Decimal Digits per 12 Hours
TROPOSPHERE						
Data Sources (Decimal digits per 12 hr)			$4.2(10)^6$			$4(10)^8$
Computer Capacity (Fraction of CDC 6600)		0.7			1.6	
Fraction Time for Data Preprocessing	0.03			0.01		
Fraction Time for Analyses	0.17 } 17% of Total Machine Capacity at FNWC			0.34 } 49% of Total Machine Capacity at AFGWC		
Fraction Time for Prognoses	0.21			0.15		
Fraction Time for Applications	0.59			0.5		
Rapid Access Storage (Decimal digits per 12 hr)			$5.1(10)^7$			$3.1(10)^8$
Fraction for Data Preprocessing	0.004			0.005		
Fraction for Analyses	0.1			0.4		
Fraction for Prognoses	0.7			0.1		
Fraction for Applications	0.2			0.5		
Slow Access Storage (Decimal digits per 12 hr)			$3.5(10)^9$			$4.7(10)^8$
Climatology Storage (Decimal digits per 12 hr)			$9.2(10)^4$			$1.8(10)^6$
OCEANS						
Data Sources (Decimal digits per 12 hr)			$2.7(10)^4$			
Computer Capacity (Fraction of CDC 6600)		0.7			0	
Fraction Time for Data Preprocessing	0.01					
Fraction Time for Analyses	0.01					
Fraction Time for Prognoses	0.001					
Fraction Time for Applications	0.98					
Rapid Access Storage (Decimal digits per 12 hr)			$4.4(10)^6$			0
Fraction for Data Preprocessing	0.04					
Fraction for Analyses	0.1					
Fraction for Prognoses	0.02					
Fraction for Applications	0.8					
Slow Access Storage (Decimal digits per 12 hr)			$3.4(10)^6$			0
Climatology Storage (Decimal digits per 12 hr)			$6.2(10)^5$			0

that at most 17% of the Monterey facilities or 8% the total DoD facilities is sacrificed in duplication.

INPUT DATA NETWORKS

The U.S. Air Force Environmental Services Support System as it exists in 1970 is diagrammed in Fig. 13. The input data networks appear in the second series of blocks in this figure. They consist primarily of the Automated Weather Network operated by the Air Force jointly in the interest of the Navy and the Air Force which derives weather and radiosonde observation data worldwide at a series of collection and transmission points for ultimate relay to Air Force Global Weather Central. These data are also passed to Fleet Numerical Weather Central and to a large extent are made available to the National Meteorological Center. Satellite data are also relayed by links shown in Fig. 13 to Global Weather Central and the ground stations of the SESS system are relayed by the astro-geoteletype network.

A similar diagram for environmental services support systems of the Navy is shown in Fig. 14. The system providing data to the Fleet Numerical Weather Central includes the Air Force operated AWN, the relay of satellite data from SOLRAD HI expected at the beginning of 1973, and the Naval Environmental Data Network which relays ship data via the Fleet Weather Centrals. A significant characteristic of present DoD environmental services support systems is dependence for data on unencoded broadcasts of weather data from synoptic stations all over the world. This is part of an international cooperation under the World Meteorological Organization. The Air Force and Navy operate a system of sites at which intercept weather radio broadcasts are accomplished. These are diagrammed in Fig. 15. It is significant that the system is dependent on international cooperation; the vulnerability of such a system for military purposes seems apparent.

The Navy Environmental Data Network in the continental United States described in Fig. 16, gathers from ships all over the world data which are relayed by way of the NEDN, ultimately to Fleet Numerical Weather Central Monterey. From Fleet Numerical Weather Central

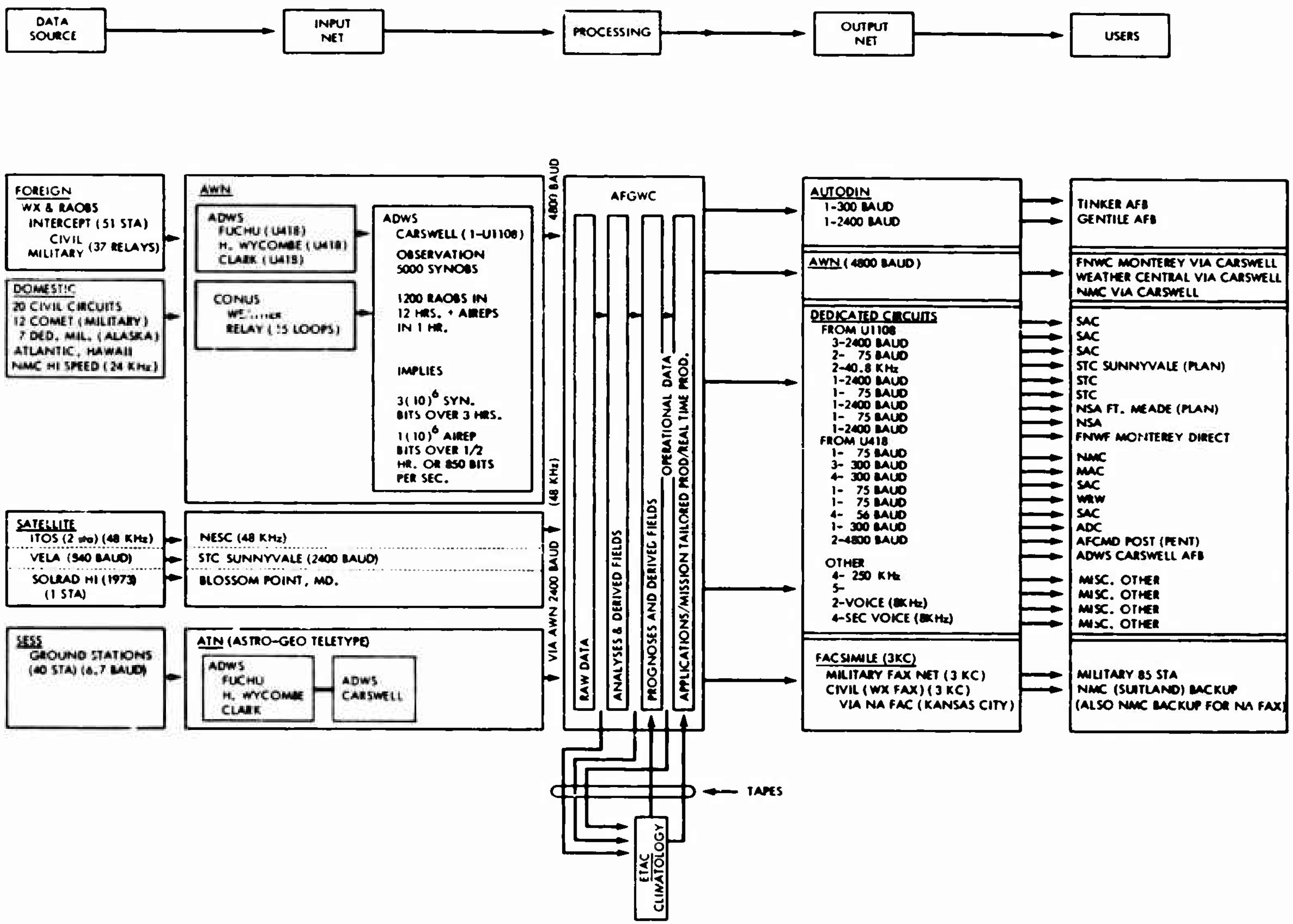


FIGURE 13. USAF Environmental Services Support System, 1970

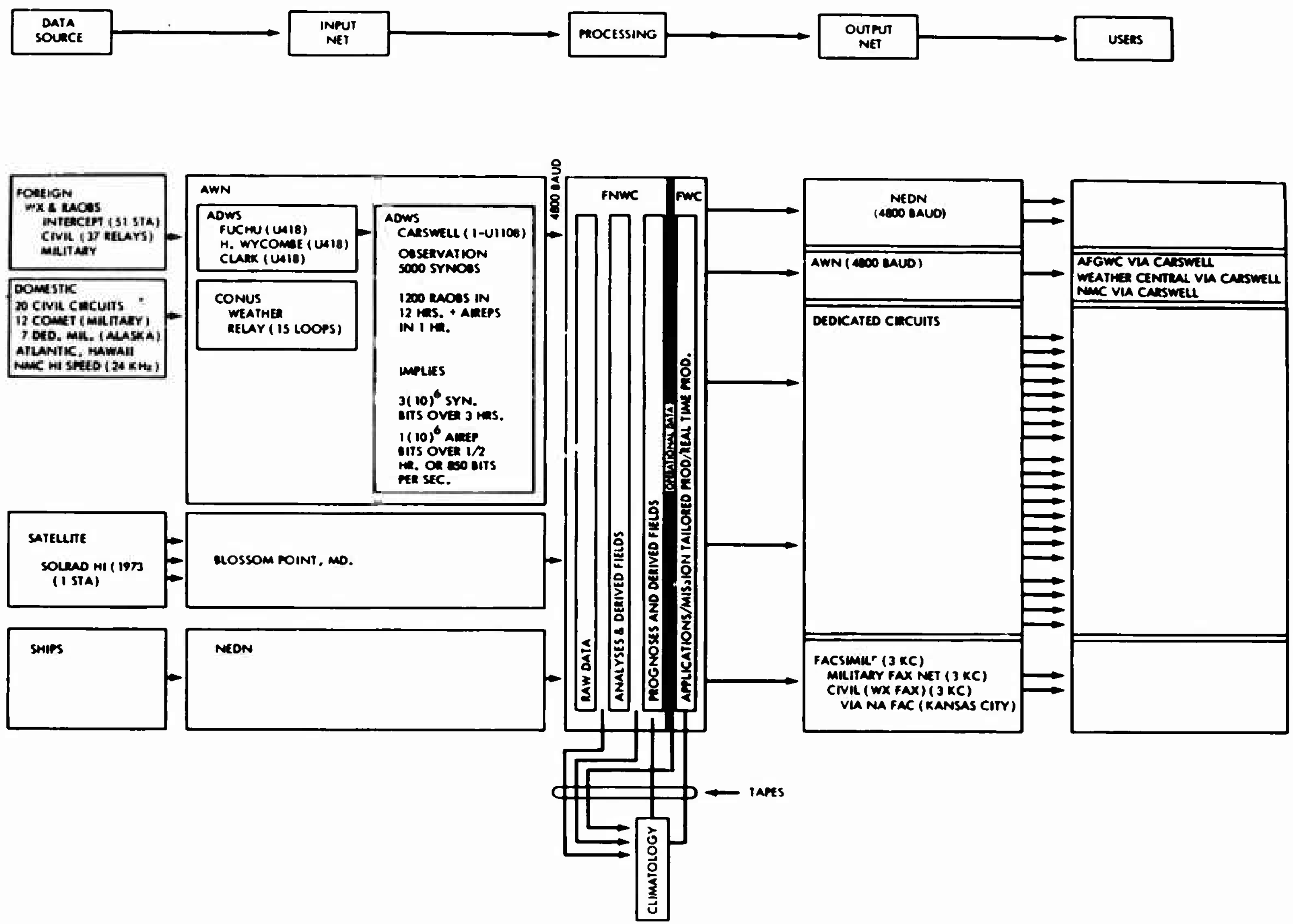


FIGURE 14. USN Environmental Services Support System, 1970

Monterey these data are then passed to the Air Force system at Carswell via the AWN. The rate of receipt of data to the weather centrals is, of course, irregular. Figure 17 plots the receipt of automatic data network to and from Air Force Global Weather Central on 29 December 1970. The 24-hour average of data as input to AFGWC is 700 bits per second; however, a 15-minute peak reaches 1650 bits per second. On the back route from AFGWC to Carswell for dissemination of weather activities, the average was 255 bits per second with a maximum 15 minute peak of 1750 bits per second. These data, especially the input data, are subject to operational delays before reaching AFGWC or FNWC. It may be seen from the plot of Fig. 18 that 90% of the surface observations arrive via the AWN at about 2½ hours after synoptic time. Seventy-six percent of radiosonde data arrives via the AWN after 4½ hours and 76% of the ship observations arrive after 3½ hours. No satellite data are received at Fleet Numerical Weather Central, however, satellite data from NESC are received at AFGWC within a few minutes.

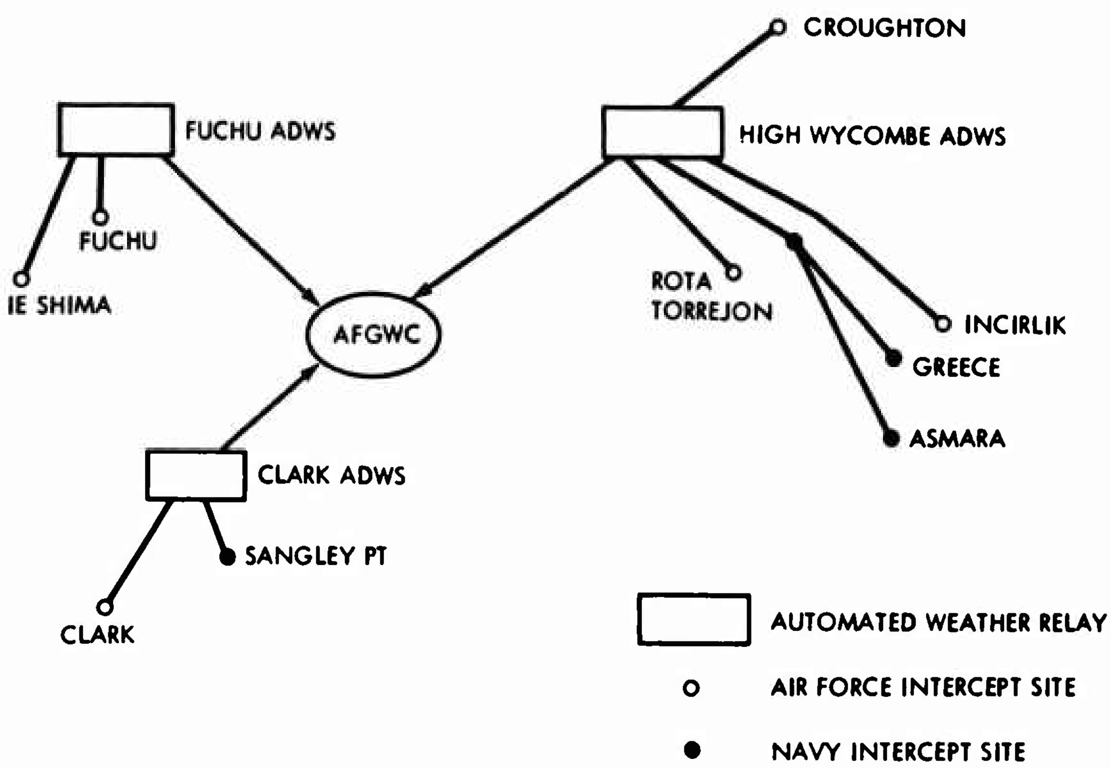


FIGURE 15. Air Force and Navy Weather Intercept Sites

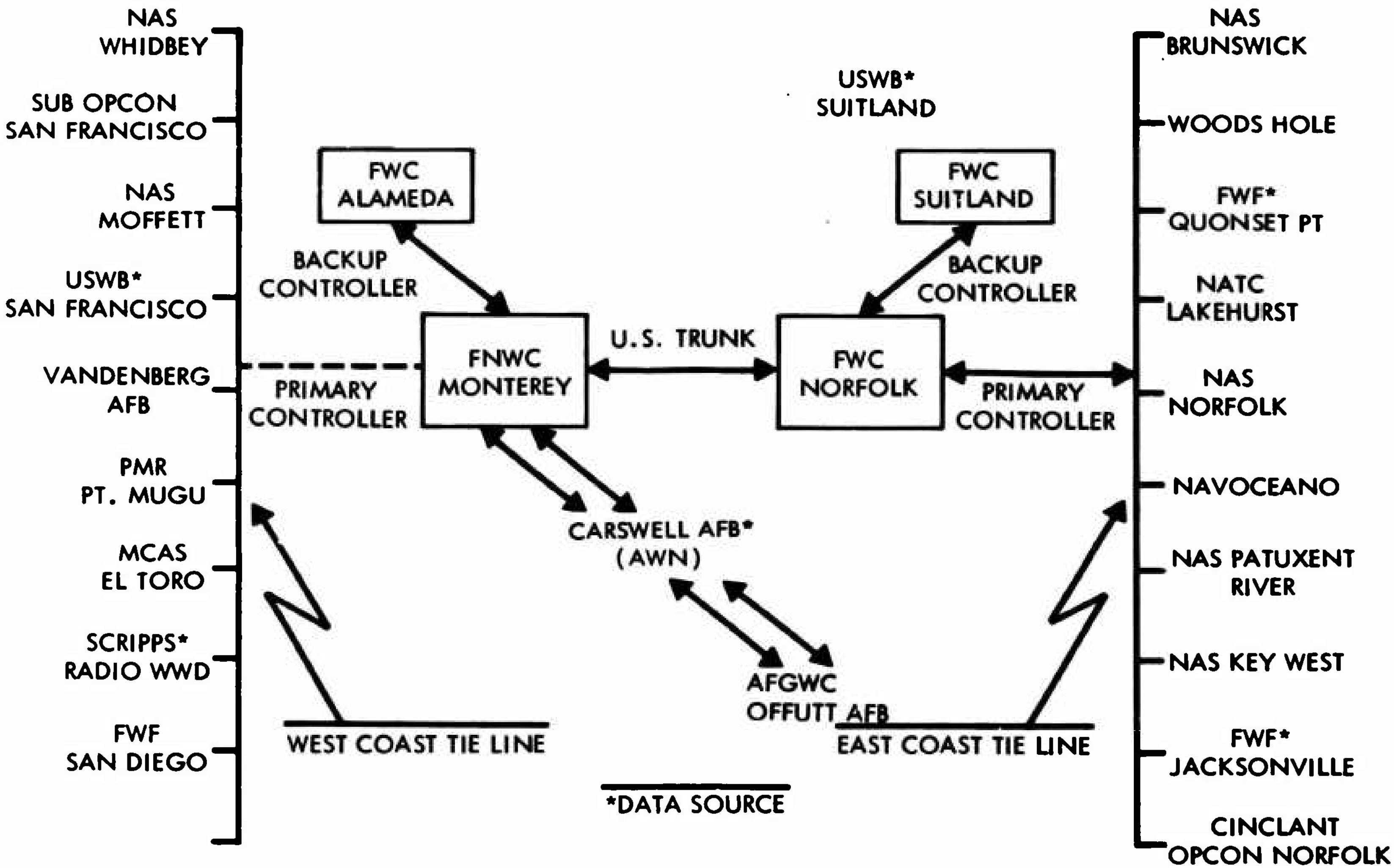


FIGURE 16. Naval Environmental Data Network in CONUS

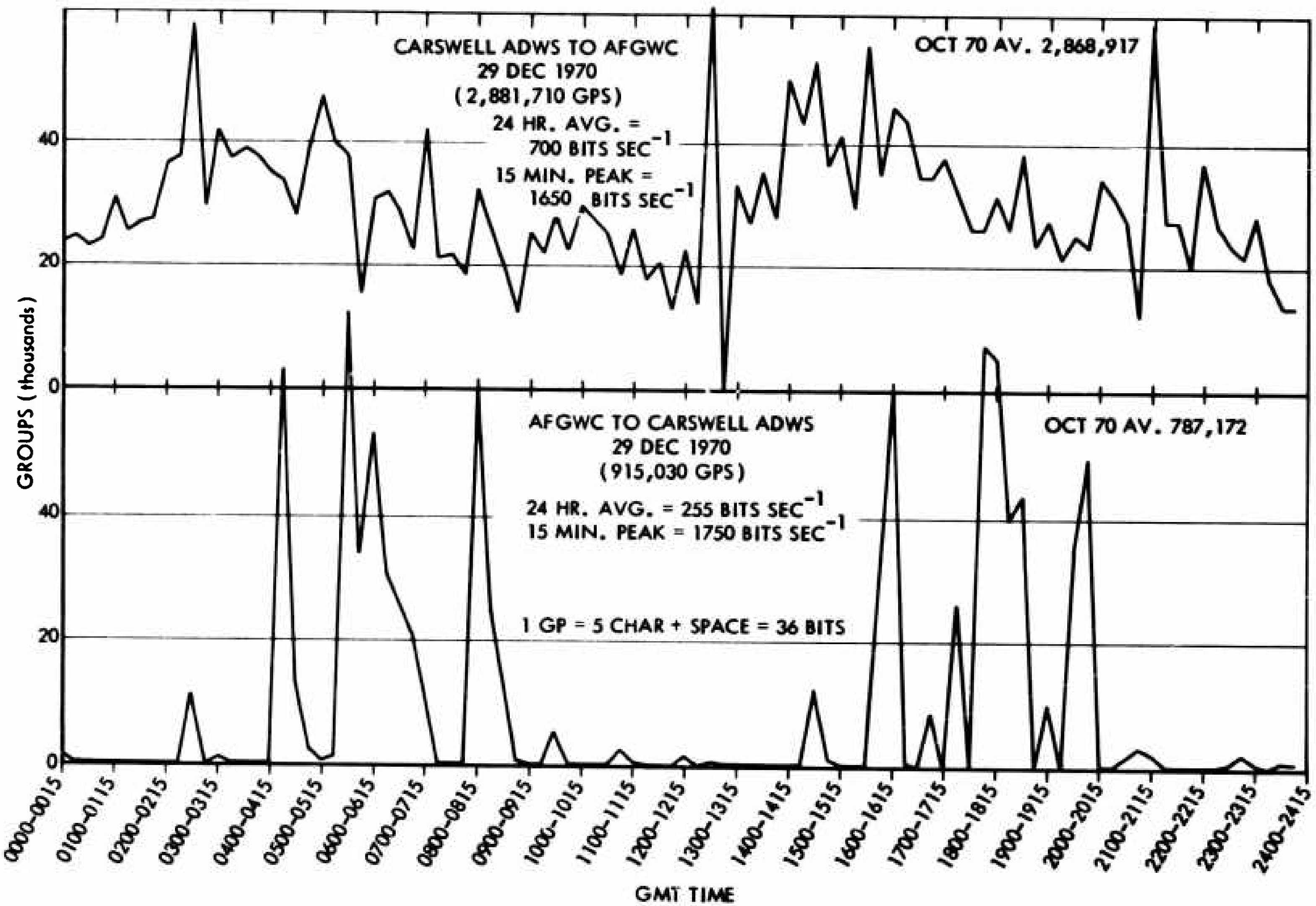


FIGURE 17. Automated Weather Networks

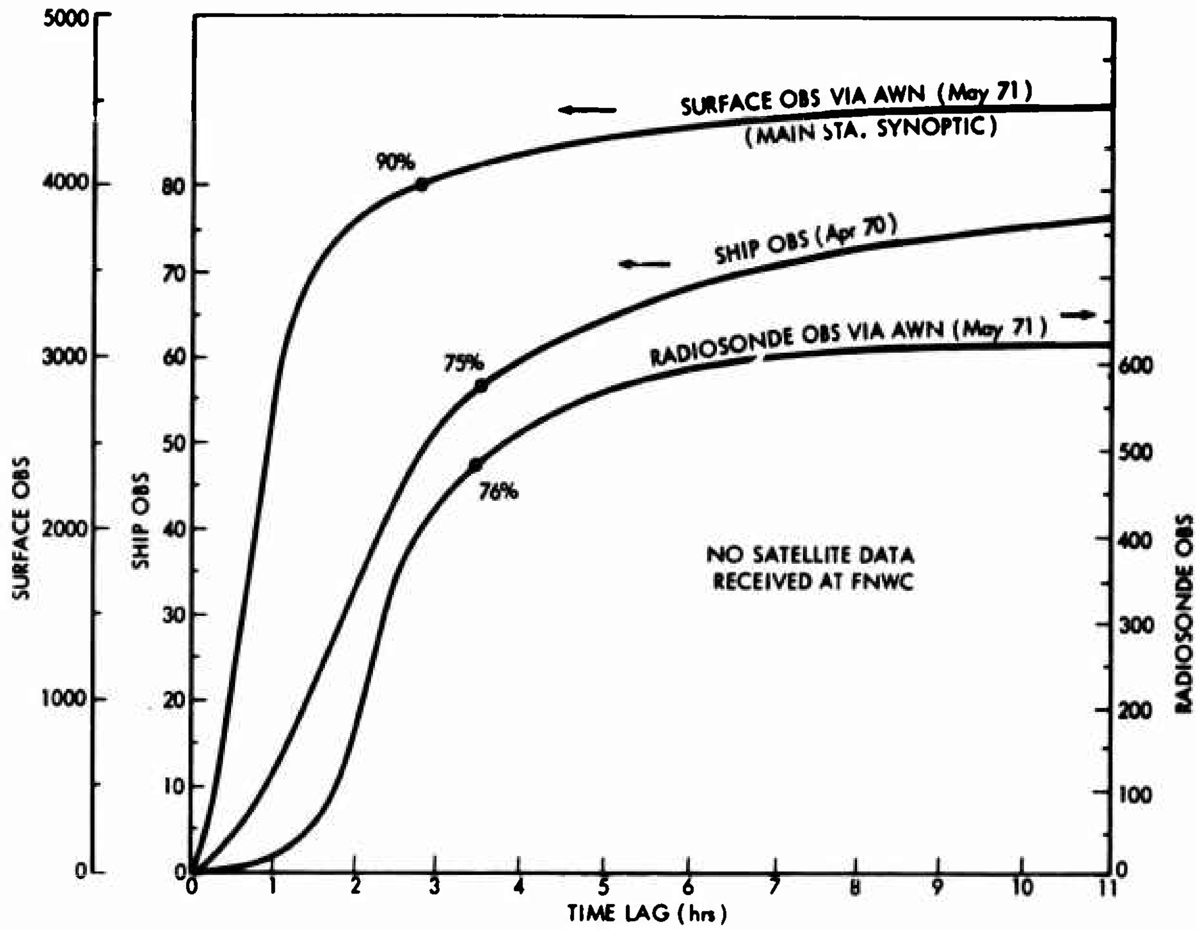


FIGURE 18. Operational Delay of Observational Data of FNWC Monterey

The increase of input data in the main represents a great problem for the weather services. This problem has been described by the Air Weather Service as shown in Fig. 19. It may be seen that the proliferation of satellite data within 1970 alone represents a 10-fold increase of data over that received from other sources including the AWN.

Output Data Networks

The product distribution of weather service products is described in Table 19. Primarily it is accomplished via the Automated Weather Network, the AUTODIN, dedicated circuits, and facsimile. The transmission of AFGWC troposphere products in 1970 is summarized in Table 20.

These data show the AWN transmitted something like 1750 bits per second maximum, the in-house data distribution was 5900 bits per second, that AUTODIN transmitted about 100 bits per second, that dedicated circuits transmitted about 639 bits per second, and facsimile 61 bits per second.

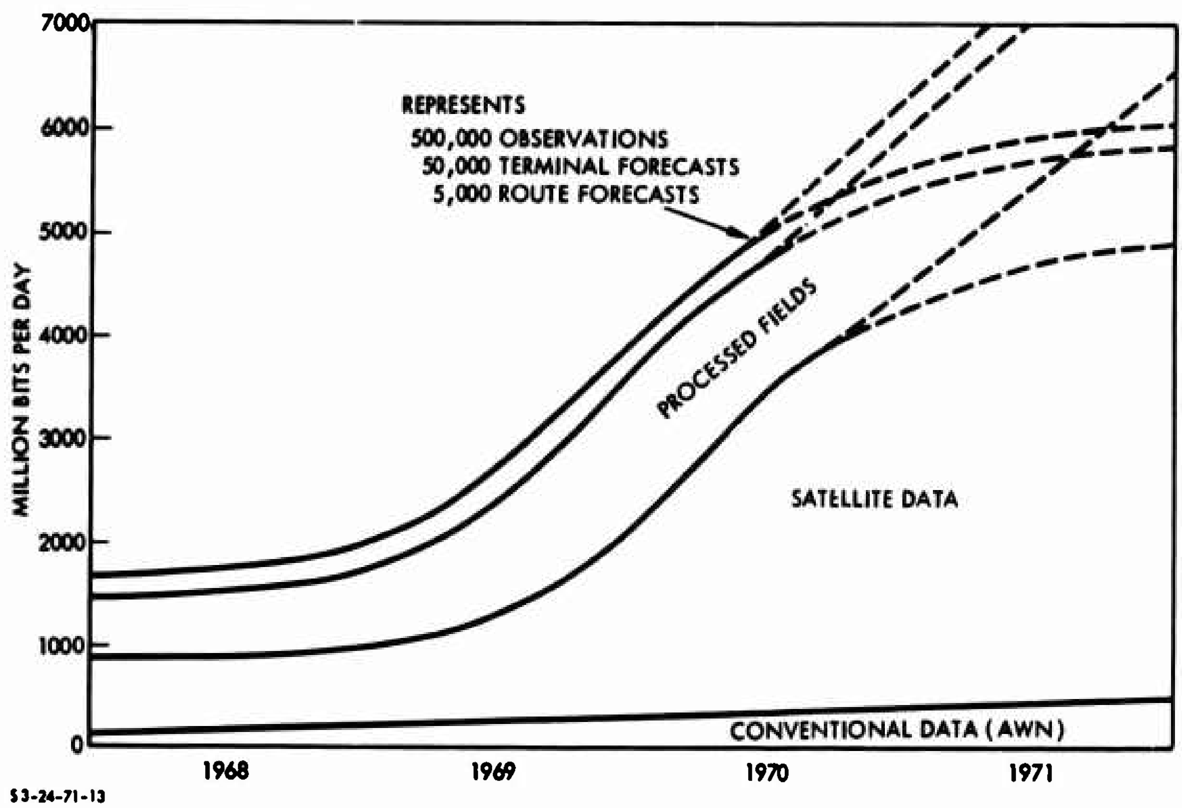


FIGURE 19. The AWS Problem

TABLE 19. PRODUCT DISTRIBUTION

- FACSIMILE
  - NOT GOOD FOR TAILORED PRODUCTS
  - REPRESENTS DUMP OF DATA BASE
- DEDICATED CIRCUITS
  - AWN: HIGH SPEED, FEW DROPS
  - LOW-SPEED (E.G., MAC CP, COMET)
  - UNDER DOD/AF SCRUTINY/REVIEW
- AUTODIN
  - COMMAND AND CONTROL COMM SYSTEM
  - MAJOR SHORTCOMING = LOCAL DISSEMINATION
  - AUTOMATED INTERFACE AT AFGWC FORTHCOMING
  - "WAY OF THE FUTURE"

TABLE 20. TRANSMISSION OF AFGWC PRODUCTS, 1970

TRANSMISSIONS OUT VIA AWN	TRANSMISSIONS OUT IN-HOUSE VIA DCT, HSP	TRANSMISSIONS OUT VIA AUTODIN	TRANSMISSIONS OUT VIA DEDICATED CIRCUITS	TRANSMISSIONS OUT VIA FAX (AFX109)
EXAMPLES: PRESSURE HEIGHT ANALYSES TEMPERATURE PRESSURE ANALYSES STATIC STABILITY ANALYSES 500 MB PROGNOSES	EXAMPLES: PRESSURE HEIGHT ANALYSES SKEW-T 500 MB PROGNOSES SFC DATA PLOT	EXAMPLES: COMPUTER FLIGHT PLANS WEATHER SUMMARIES ROUTE FORECASTS	EXAMPLES: BUIC WIND MESSAGES SFC SYNOPTIC OBSERVATIONS TAFORS	EXAMPLES: SKEW-T CLOUD FORECAST 500 MB HEIGHT FORECAST
ESTIMATED TRANSMISSIONS RATE OUT: 8200 BITS SEC^{-1} ESTIMATED 1750 BITS SEC^{-1} RECORDED	ESTIMATED TRANSMISSIONS RATE OUT: 5900 BITS SEC^{-1}	ESTIMATED TRANSMISSIONS RATE OUT: 102 BITS SEC^{-1}	ESTIMATED TRANSMISSIONS RATE OUT: 639 BITS SEC^{-1}	ESTIMATED TRANSMISSIONS RATE OUT: 61 BITS SEC^{-1}
CHANNEL CAPACITY AWN CAPACITY 4800 BITS SEC^{-1}	CHANNEL CAPACITY 7 HSP ($1.6(10)^9$ CHAR* DAY^{-1}) 10 DCT ($4.3(10)^8$ CHAR* DAY^{-1}) ($1.5(10)^6$ BITS SEC^{-1} AVG)	CHANNEL CAPACITY 2400 BITS SEC^{-1}	CHANNEL CAPACITY $3.5(10)^3$ BITS SEC^{-1}	CHANNEL CAPACITY $1.7(10)^5$ SCANS** DAY^{-1} (250 BITS SEC^{-1} AVG)

*1 CHAR IMPLIES 6 BITS
1 DAY = 86400 SEC
1 CHAR/DAY = $7.4(10)^{-4}$/BITS SEC^{-1}
HSP 132 CHAR $(LINE)^{-1}$
1200 LINES $(MIN)^{-1}$
DCT 128 CHAR $(LINE)^{-1}$
250 LINES $(MIN)^{-1}$

**120 SCANS PER MIN
1 SCAN = 125 BITS
1 DAY = 86,400 SEC
1 SCAN/DAY = $1.45(10)^{-3}$ BITS SEC^{-1}

In Table 21 are shown the transmissions of Fleet Numerical Weather Central troposphere and ocean products in 1970. From this it may be seen that the AWN transmitted about 5.8 bits per second, that the NEDN transmitted 1300 bits per second, that the AUTODIN transmitted 16 bits per second plus special requests that the NEDN tie-line transmitted out 1540 bits per second, that the facsimile to Norfolk transmitted 4.6 bits per second, and that the in-house transmission distribution was 4600 bits per second.

As has been described before, the Navy relies on the use of Fleet Weather Centrals as data relays. These Fleet weather centrals also make other inputs which are addressed to specific needs of the forces and theatres in which they operate. The facsimile schedule of a fleet weather central is diagrammatically given in Fig. 20.

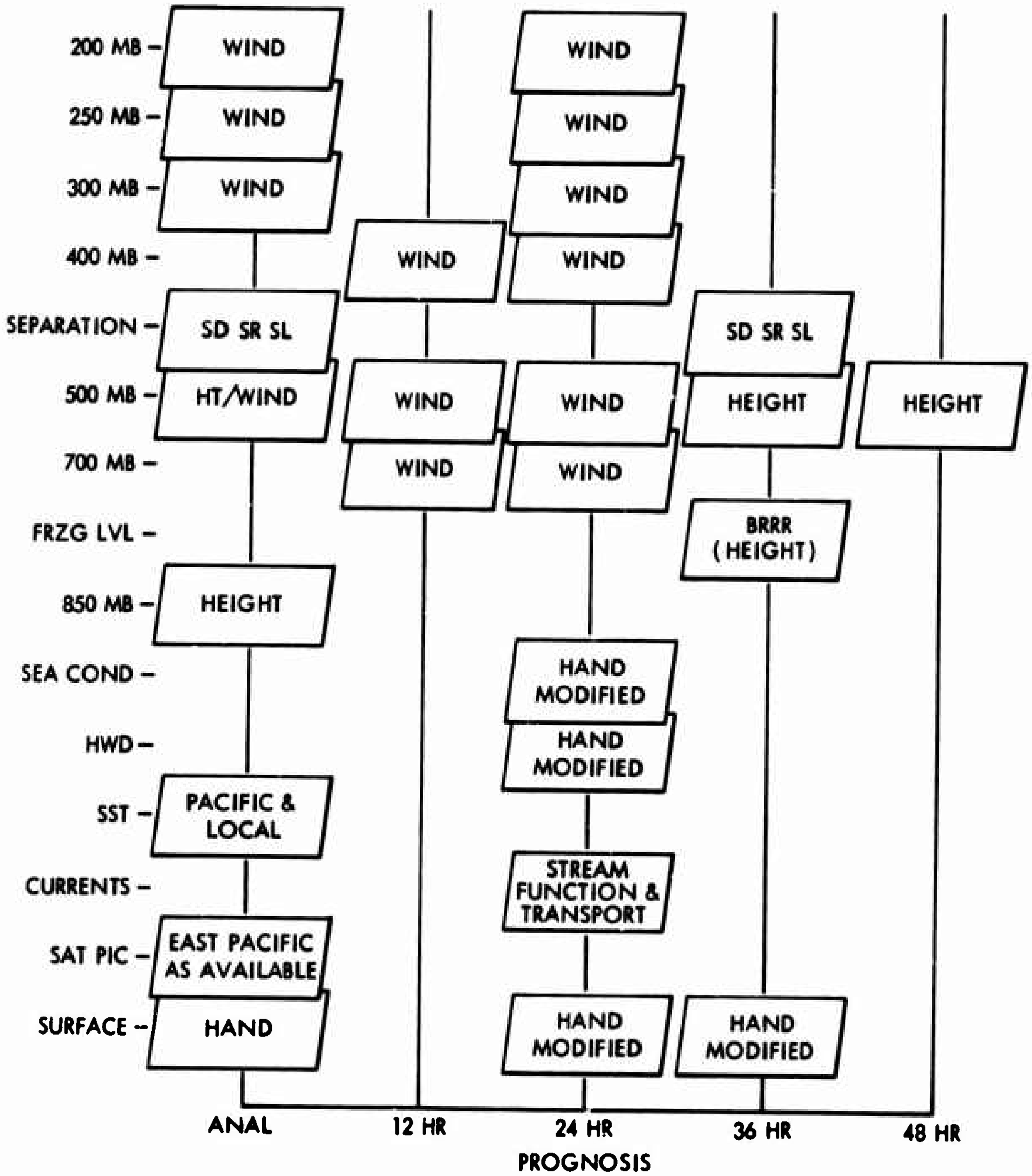


FIGURE 20. FWC Pearl Harbor Facsimile Schedule

TABLE 21. 1970 TRANSMISSION OF FNWC TROPOSPHERE AND OCEAN PRODUCTS

Trans Out CARSWELL	Trans Out NEDN	Trans Out AUTODIN	Trans Out Tieline CAT*/Charts	Trans Out FAX to Norfolk	Trans Out In House
OCEANIC					
$0.1(10)^6$ bits day^{-1}	$26.0(10)^6$ bits day^{-1}	$0.6(10)^6$ bits day^{-1}	$40.0(10)^6$ bits day^{-1}	0.0	$100.2(10)^6$ bits day^{-1}
TROPOSPHERIC					
$0.4(10)^6$ bits day^{-1}	$86.0(10)^6$ bits day^{-1}	$0.7(10)^6$ bits day^{-1}	$93.0(10)^6$ bits day^{-1}	$0.4(10)^6$ bits day^{-1}	$295.6(10)^6$ bits day^{-1}
TOTAL					
$0.5(10)^6$ bits day^{-1}	$112.0(10)^6$ bits day^{-1}	$1.5(10)^6$ bits day^{-1}	$133.0(10)^6$ bits day^{-1}	$0.4(10)^6$ bits day^{-1}	$395.8(10)^6$ bits day^{-1}
5.8 bits sec^{-1}	1300 bits sec^{-1} + special requests (These data are compacted 0.25 to 0.05)	1.6 bits sec^{-1} + special requests	1540 bits sec^{-1}	4.6 bits sec^{-1}	4600 bits sec^{-1}

*CAT = Collect and Transmit Unit

Significant Features

Significant features of the Air Force Global Weather Central and Fleet Numerical Weather Central environmental computation activity of 1970 are tabulated in Table 22. The Air Force Global Weather Central is seen to concentrate on troposphere and the lower stratosphere with the emphasis on boundary layer near the earth's surface and on real-time response to query, and with some attention to the space environment. The Fleet Numerical Weather Central puts emphasis on the marine environment dividing its attention about equally between the tropospheric and the oceanic. The central processing utilization is low at present at Global Weather Central but is expected to increase strongly by the end of 1971. The central processor utilization at Fleet Numerical Weather Central is high. They have been effective in operating as a policy about 20% of computer capacity for development. The U.S. Air Force AWN provides chief data input for both the Fleet Numerical Weather Central and Global Weather Central with contribution to the

TABLE 22. SIGNIFICANT FEATURES OF AFGWC AND FNWC ENVIRONMENTAL COMPUTATIONS, 1970

AFGWC	FNWC
• Concentrate on Troposphere and Lower Stratosphere: Emphasis on Boundary Layer North of 20° North Latitude and Real-Time Query-Response Capability; Some Attention to Space Environment; About Half Present Capacity is Dedicated to Highly Classified Special Projects	• "Tropospheric Stratosphere" and "Oceanic" Computations are About Equally Divided; Emphasis On Marine Environment of Northern Hemisphere
• Central Processing Unit Utilization is 48%, of Which 20% is Absorbed by the Executive Routine, Communications and Real-Time Operations	• Central Processor Utilization is About 80%; Development is About 20% of the Computer Capacity
• USAF AWN Provides Chief Data Input for Both FNWC, and AFGWC and Contributes to NMC	• Chief Source of Tropospheric Data is the USAF AWN
• Data Decode and Validation Requires One to Ten Hours For Each Analysis Period Limited by Rate of Receipt and Utilizes 1 to 4% of Computer Capacity	• Data Decode and Validation Requires 1 to 10 Hours For Each Analysis Period Limited by Rate of Receipt and Utilizes 3% of Computer Capacity
• Overall Policy Allocates 25% of Capacity to Each of the Meteorological Field Computations, Applications, Classified Applications and Development. For Troposphere and Lower Stratosphere Computations, Analyses of Basic Fields Requires 34% of Exploited Machine Capacity, Prognoses 15% and Applications 50% of the Machine Capacity	• Overall Policy Allocates to Data Processing 3%; Analyses 5%; Prognoses 16%; Scheduled Applications 18% Non-Scheduled Applications 18%; Development 20%; Maintenance 20% • For Tropospheric Computations, The Analysis of Basic Fields Requires 17% of Exploited Machine Capacity, Prognoses of Basic Fields 21%, and Derived Products 62% of the Machine Capacity • For Oceanic Computations, Basic Fields of the State Variables, Over and Above the Atmospheric Field Computations Also Required for Ocean Fields, Require 2% of the Effort; Sound Propagation Analyses Require 98% of the Effort.
• For Tropospheric and Stratospheric Prognoses; The Filtered Baroclinic Models, Cloud Models and Boundary Layer Model Utilize About 120 min of the 360 min for All Basic Field Computations in 12 Hours of Four U-1108	• For Tropospheric Prognoses; the Barotropic Model Used Prior to August 1970 Required 66 min of the 118 min for All Basic Field Computation. The Primitive Equation Model, Better for Prognoses, Requires 60 min of Computation by Two CDC 6500

National Meteorological Center. This data source is particularly vulnerable to vagaries of international cooperation. Data decode and validation at present require one to four percent of the computer capacity of each center. The analyses and prognoses of basic fields require about 17 percent of the exploited machine capacity at Fleet Numerical Weather Central. Programs duplicating those of FNWC Monterey comprise less than 10 percent of effort of the Air Force Global Weather Central. The 17 percent of time dedicated to tropospheric analyses and prognoses appears to be the principal area of potential duplication between the two centers. On this basis less than 8 percent of the total DoD capacity is used redundantly. It is unlikely that two separate centers can be operated with much smaller waste motion than this. It is moreover plausible that this apparent redundancy is indeed the most efficient way of carrying on the work since it must be balanced against the loss of machine time in buffering data computed by and received from another installation. A final point of significance in the comparison of AFGWC and FNWC computational efforts is that the primitive equation model recently innovated at FNWC is better for forecasting of tropospheric data and requires in the aggregate less machine time than the barotropic models used to derive the same outputs.

III. MILITARY NEEDS FOR ENVIRONMENTAL DATA

Before discussing specific military needs for environmental data, it is necessary to understand why these military needs cannot be met by the current and programmed civilian systems. The U.S. civilian environmental data gathering and data reduction systems are primarily oriented toward providing weather information to the continental United States. They are totally dependent on open international co-operation through the World Meteorological Organization controlled through the United Nations. Therefore they cannot handle secure data for the U.S. without some embarrassment to and degradation of their civilian mission. Because of their different domain of interest, the U.S. civilian systems are not designed to supply the kinds of data required by the military nor are they capable of meeting military demands for timeliness. Immediacy of military environmental information is often critical. All of these reasons have, of course, led to the development of separate military environmental services in the first place. In short, unique military needs are best met by a system dedicated to these needs.

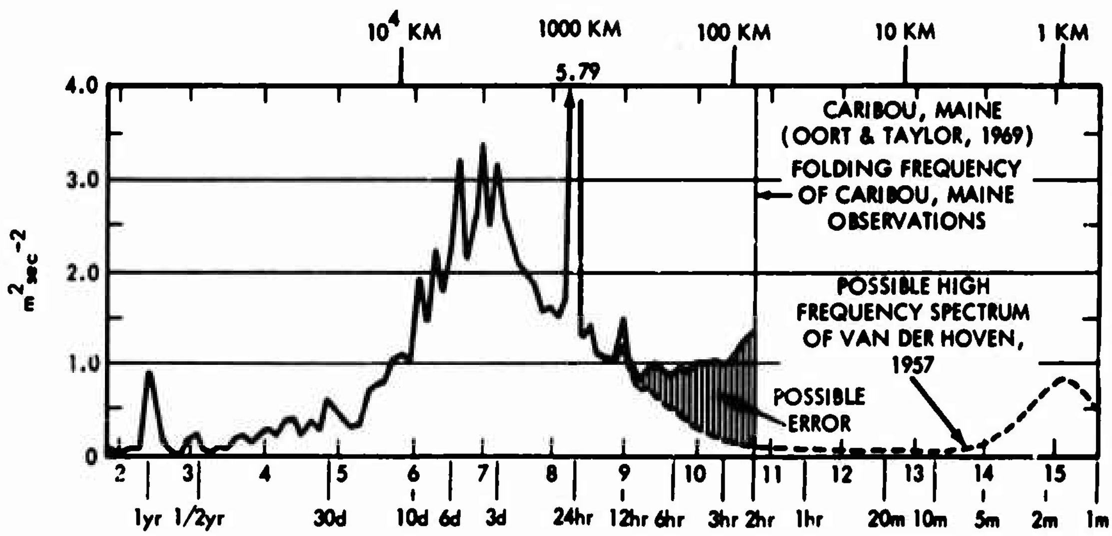
In assessing the military needs for environmental data, it is relatively easy to use the conventional wisdom by which we derive the needs of 1970. Technological forecasting for the future is, however, a more difficult matter. It is necessary in technological forecasting to anticipate needs which while evident today may be unmet today because of inadequacies of current technology. Unmet needs of the future drive change in technology. Technological developments will be strongly influenced by the use of the satellite and the use of the most modern computers.

Future needs may be estimated by several different methods of technological forecasting. Linear extrapolation to project future expansion has in the past proved totally inadequate. Exponential extrapolation on the other hand leads to widely variable estimates depending on the exponent used. In this study, a third approach has been utilized. First, it was recognized that the development of the two new tools, i.e., the meteorological satellite and the high-speed electronic computer, represents a technological breakthrough in environmental study. The question then became, "What environmental sensor systems and data reduction facilities can the Services advantageously utilize to meet recognized military needs in 1975?" By "advantageously utilize" it is meant that benefits to be derived from the environmental data must clearly outweigh the cost of obtaining and processing that data. It has not been the purpose of this study to make cost/benefit analyses. We have forecast the future burden to be placed on DoD computer centers to meet all the premised needs.

A comparison of military needs for environmental data with the capability of equipments which are potentially available in 1975-1980 leads to the estimation that the DoD computer capacity in this time period should reach 18,000 bits per microsecond. The recent history of development of DoD computer capacity has in the eight years prior to 1969 doubled every one and one-half years. An extrapolation of that doubling leads to the 18,000 bits per microsecond figure in 1978.

There is a physical basis for forecasting military needs for environmental data. The physical basis for several examples with cautions are discussed in the following paragraphs.

A caution is indicated by Fig. 21 which shows on a spectrum of the low-level wind speed, the aliasing error which affects our computing programs of today and which results from the way meteorological measurements are made. The possible error at the period corresponding to a 3- to 6-hour synoptic interval is almost an order of magnitude. Environmental computations must take into account the characteristics of the instruments which are measuring the data which they use. Instrument



HORIZONTAL WIND SPEED SPECTRA

SCALE LENGTH		DISSIPATION RATE	DIFFUSIVITY	VELOCITY	PREDICTABILITY TIME	
KM	CM	CM^2SEC^{-3}	CM^2SEC^{-1}	$CM\ SEC^{-1}$	SEC	DAYS-HOURS
5000	5×10^8	10	1.2×10^{11}	1.9×10^3	2.6×10^5	3.0d
		1	5.8×10^{10}	9.4×10^2	5.4×10^5	6.3d
500	5×10^7	10	5.8×10^9	9.4×10^2	5.4×10^4	15.0hr
		1	2.7×10^9	4.2×10^2	1.2×10^5	1.4d
50	5×10^6	10	2.7×10^8	4.2×10^2	1.2×10^4	3.3hr
		1	1.2×10^8	2.0×10^2	2.5×10^4	6.9hr
5	5×10^5	10	1.2×10^7	2.0×10^2	2.5×10^3	0.7hr
		1	5.8×10^6	9.2×10^1	5.4×10^1	1.5hr

VELOCITY, DIFFUSIVITY COEFFICIENT AND PREDICTABILITY TIME APPROPRIATE TO VARIOUS SCALES OF MOTION AND DISSIPATION RATES (AFTER ROBINSON, 1967)

FIGURE 21. Computational Aliasing Error and Predictability of Tropospheric Phenomena

designers should take into account the computational technique which uses their data.

Another caution brought out in Fig. 21 relates to the predictability of tropospheric phenomena. Certain tropospheric phenomena have a characteristic lifetime beyond which it is difficult to predict in an deterministic way its future fate. Using the data of Robinson, it is shown in the table of the lower part of Fig. 21 that the phenomena of characteristic length five kilometers, such as a cloud of thunderstorm, may expect to have a predictable lifetime of about an hour whereas items of length characteristic 500 kilometers may be expected to survive for more than a day. Phenomena of characteristic length 5000 kilometers may last from three to six days. These lifetimes represent limits of predictability by deterministic techniques. Of course, predictability in a probabilistic manner can be for much longer.

In Fig. 22 is a comparison of a worst-case climatological density model and potential military application needs for density and temperature data plotted as a function of tolerable uncertainty of density and of temperature versus altitude. Shown is the tolerance of uncertainty of data for weather prediction, radio communication, satellite orbit prediction, and ICBM targeting. It may be seen that a great number of military needs require data more exact than is provided by climatological averages.

Figure 23 is a similar curve relating a climatological wind model and the needs for specific applications of wind data. Here again we see that the military applications are more exacting than may be encountered on a climatological basis.

Figure 24 shows the fractional change in temperature which is due to each of various bands to be measured in the extreme ultraviolet by SOLRAD HI beginning in 1973. The solar flux is such bands using a typical radiation and atmospheric model may be expected to cause temperature changes in excess of the values to which the HF communications and satellite drag systems may be expected to be tolerant.

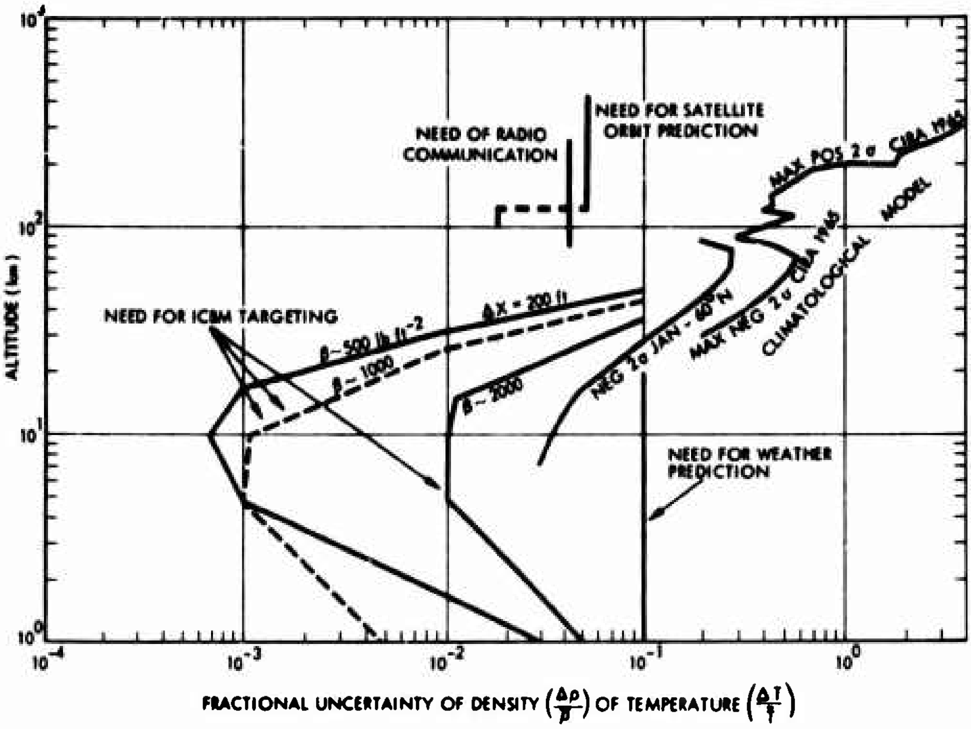


FIGURE 22. Comparison of a Climatological Density Model and Potential Application Needs

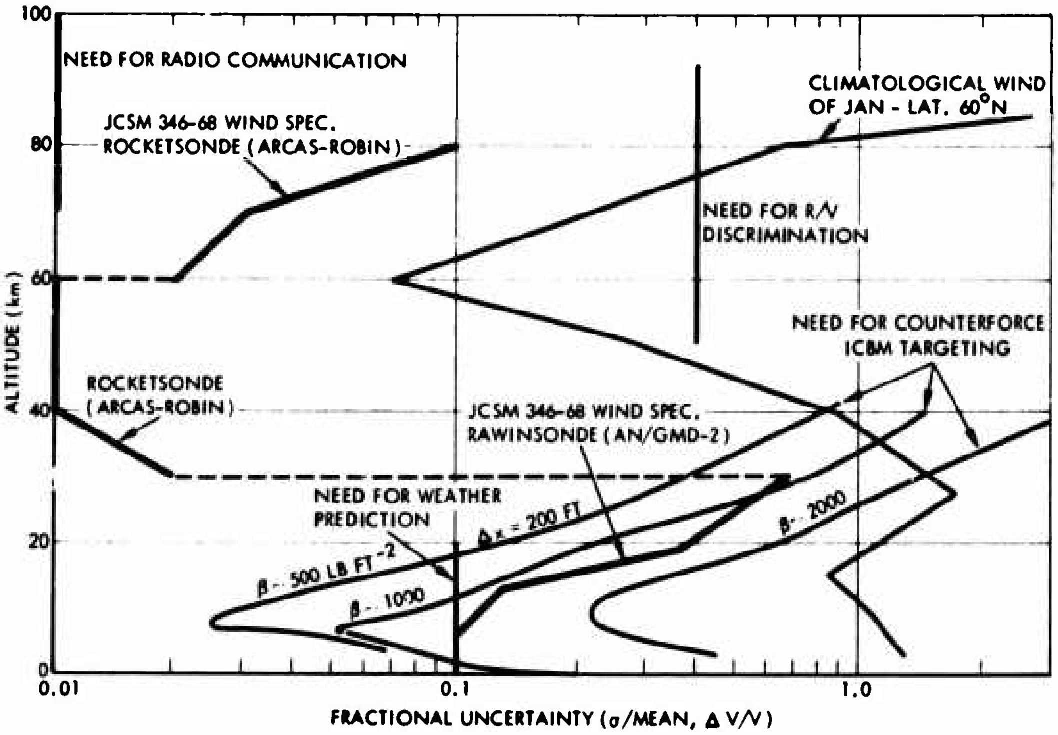


FIGURE 23. Comparison of a Climatological Wind Model, JCSM 346-68 Wind Specification for Measurements and Potential Application Needs

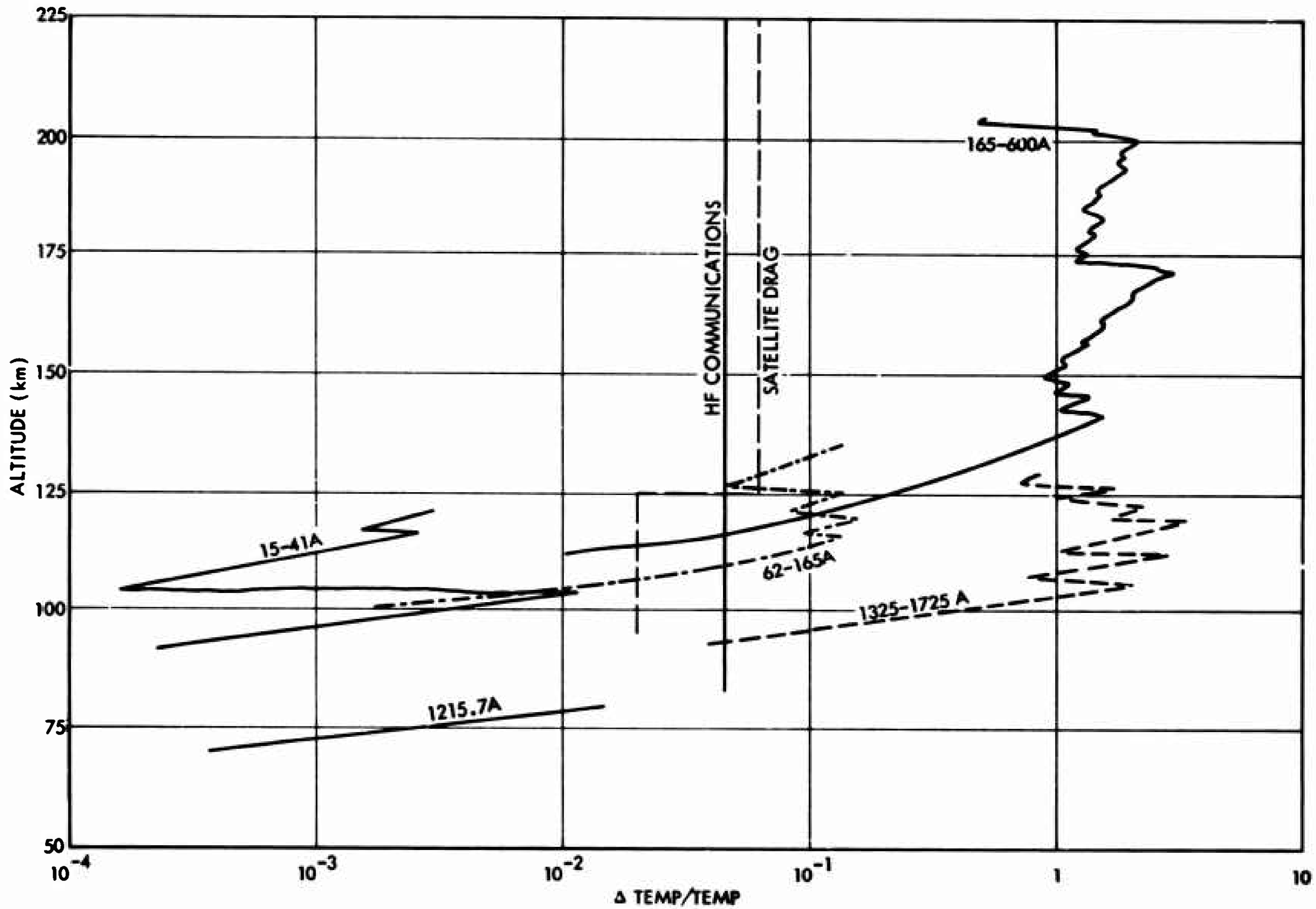


FIGURE 24. Heating by Solar Radiation

TABLE 23. ALLOWABLE FRACTIONAL UNCERTAINTY OF ATMOSPHERIC PARAMETERS

APPLICATION	ALTITUDE RANGE (KM)	TEMPERATURE T	PRESSURE P	WATER VAPOR PRESSURE P_W	TOTAL NUMBER DENSITY n_{TOT}	OZONE DENSITY $n(O_3)$	ELECTRON DENSITY N_e	VELOCITY $\underline{V}$	REFRACTIVE INDEX N	PARTICLE DIAMETER D	ENERGY ABSORPTION $q(\lambda)$	MAGNETIC FLUX ℓ
		FRACTIONAL UNCERTAINTIES OF ATMOSPHERIC PARAMETERS										
WEATHER PREDICTION	(0-20 KM)	$(10)^{-2}/2(10)^{-1}$	$(10)^{-1}/2(10)^{-1}$	$(10)^{-1}/(10)^{0}$	$(10)^{-1}/2(10)^{-1}$	✓		$(10)^{-1}/(10)^{0}$ HORIZ $(10)^{-3}/(10)^{0}$ VERT			✓	
RADIO COMMUNICATION	(7-320 KM)	$(10)^{-2}/(10)^{-1}$		$(10)^{-2}/(10)^{0}$	$(10)^{-2}/(10)^{0}$		$(10)^{-2}/(10)^{0}$	$(10)^{-2}/(10)^{0}$	✓	✓	✓	✓
BALLISTIC MISSILE TARGETING	(0-50 KM)		✓		$(10)^{-3}/3(10)^{-1}$			$3(10)^{-1}/(10)^{0}$			✓	
SATELLITE ORBIT PREDICTION	(125-200 KM)	✓	✓		$5(10)^{-2}/3(10)^{0}$			✓			✓	
DISCRIMINATION IN BMD	(50-130 KM)	$2(10)^{0}/2(10)^{-1}$			$2(10)^{0}/6(10)^{-1}$			$4(10)^{-1}/4(10)^{-1}$				

NOTE:

FIGURES WITH RESPECT TO APPLICATIONS ARE THE TOLERABLE FRACTIONAL UNCERTAINTIES EXPRESSED IN THE NUMERATORS UNCERTAINTIES OF THE CLIMATIC AVERAGES IN THE DENOMINATORS.

CHECKS INDICATE THAT THE PARAMETER IS SIGNIFICANT OR MEASURABLE BUT THE RELEVANT UNCERTAINTIES HAVE NOT BEEN EVALUATED.

Table 23 shows allowable fractional uncertainties of atmospheric parameters for a variety of atmospheric parameters for various applications of military interest. The numerator shown in Table 23 indicates the tolerable fractional uncertainty. The actual uncertainty of the climatic average at the altitude affected is shown in the denominator. It is clear from the data of Table 23 that nearly all military applications listed require the measurement of atmospheric parameters and these applications range in altitudes of interest from the surface up to more than 300 kilometers.

The DoD needs for tropospheric data are summarized in Table 24; the tropospheric data are necessary for ICBM targeting, tactical bombing, aircraft routing, operation of air bases and ships, and fallout detection.

TABLE 24. DOD NEEDS FOR TROPOSPHERIC DATA

• ICBM TARGETING	VARIATIONS OF WIND AND DENSITY AFFECT PRECISION TARGETING OF ICBM
• TAC BOMBING	INACCURACY OF WEATHER FORECAST CAN DOUBLE OR TRIPLE TIME FOR 14 DAY, 1000 SORTIE, BARE-BASE MISSION
• SAC, MAC, TAC, NAVAIR	AIRCRAFT ROUTING; CONTRAIL PREDICTION; CLOUD COVER PREDICTION; TURBULENCE PREDICTION; WINDS ALOFT PREDICTION; FREEZING LEVEL PREDICTION
• AIR BASE OPERATIONS	SEVERE WEATHER PREDICTION
• SHIPS	OPTIMUM TRACK SHIP ROUTING; CYCLONE PREDICTION; WIND-WAVE AND SWELL PREDICTION
• FALLOUT DETECTION	FALLOUT PREDICTION

The DoD needs for oceanic data are summarized in Table 25; there are needs for weather prediction, for the operation of ships including optimum track ship routing, for anti-submarine warfare and for pro-submarine warfare. Both of these latter involve the prediction of sound propagation ranges. The pro-submarine warfare is concerned with the prediction of subsurface currents and waves such as may have accounted for the loss of the USS THRESHER.

TABLE 25. DOD NEEDS FOR OCEANIC DATA

WEATHER PREDICTION	SEA-AIR HEAT EXCHANGE SEA-STATE FORECAST
SHIPS	SEA SURFACE TEMPERATURE; WIND WAVES, SEA WAVE PREDICTION; OPTIMUM TRACK SHIP ROUTING; SURFACE AND SUBSURFACE CURRENT PREDICTION
ANTI-SUB WARFARE	SOUND PROPAGATION RANGES; TEMPERATURE AND DENSITY PROFILES
PRO-SUB WARFARE	SOUND PROPAGATION RANGES: TEMPERATURE AND DENSITY PROFILES; SUBSURFACE CURRENTS AND WAVES

DoD needs for stratosphere, mesosphere, and thermosphere data are summarized in Table 26. They involve the needs for command and control, surveillance and detection, and satellite control and track.

Table 27 shows possible trends in future DoD environmental services computations of the troposphere-stratosphere. These trends involve the analysis with global coverage, the use of satellite derived data inputs, determination of clouds, winds, and severe weather, use of a smaller grid scale extended period forecasting, and detailing of relations with the ocean boundary layer.

In Table 28 are possible trends in future environmental services computations in the oceans. These involve spectral sea and

swell analysis and prediction, thermo and salinity structure analysis, prediction of the ocean hydrodynamics, prediction of ice, mapping of sound propagation, the heat exchange between the air and the sea, and the mapping of ambient noise in the ocean.

Table 29 shows possible trends in the future DoD environmental services computations of the stratosphere, mesosphere and thermosphere. These involve global moddeling of the upper atmosphere with prognoses up to 24 hours and the use of satellite techniques for measuring atmospheric emission in the stratosphere, atmospheric absorption of solar radiation in the mesosphere, and thermosphere and solar radiation monitoring.

TABLE 26. DOD NEEDS FOR STRATO-, MESO-, AND THERMOSPHERE DATA

• COMMAND AND CONTROL	
• C&C SYSTEMS	RELIABILITY AND SPEED OF SERVICE OF COMMUNICATIONS
• GENERAL COMMUNICATIONS	ELF, VLF AND LF COMMUNICATIONS
• SURVEILLANCE AND DETECTION	
• OHD RADARS	PROPAGATION OF HF RADIO TRANSMISSION (MUF, LUF)
• SAT SYSTEM 647	PROPAGATION AND BACKGROUND OF ULTRAVIOLET RADIATION
• AEDS	PROPAGATION OF X-RAYS AND NUCLEAR PARTICLES
• SAFEGUARD	PROPAGATION OF RADAR AFFECTED BY ELECTRON DENSITY VARIATIONS
• SATELLITE CONTROL AND TRACK	
• SPACETRACK, SPASUR, AFSCF	SOLAR ELECTROMAGNETIC AND PARTICLE RADIATION CHANGES AFFECT ATMOSPHERIC DENSITY PROFILES, CAUSING CHANGES OF SATELLITE DRAG, AFFECTING ORBIT PREDICTION
	REAL TIME SOLAR FLUX MONITORING

TABLE 27. POSSIBLE TRENDS IN FUTURE DOD ENVIRONMENTAL SERVICES COMPUTATIONS IN TROPOSPHERE/STRATOSPHERE

DOMAIN OF INTEREST

- GLOBAL ANALYSIS
- USE OF SATELLITE-DERIVED DATA INPUT FOR DENSITY (PRESSURE), WATER VAPOR, TEMPERATURE (HEAT SOURCES)
- CLOUD, WIND AND SEVERE WEATHER COVERAGE OF THE ENTIRE SPHERE (GLOBAL AND WINDOW)
- SMALLER GRID SCALE
- EXTENDED PERIOD FORECASTING
- RELATIONS WITH OCEAN BOUNDARY LAYER
  - LOWER BOUND TO TROPOSPHERE
  - SEA-AIR HEAT EXCHANGE
  - OCEAN WEATHER

APPLICATIONS

TRAFFICABILITY ON LAND

COMPUTER FLIGHT PLAN

TARGET FORECASTING

PARACHUTE DROPS

AIRCRAFT RECOVERY

SEA-STATE PREDICTION

LOWER BOUND TO ANALYSES OF STRATOSPHERE

MISSILE BALLISTIC FORECASTING

TERMINAL FORECASTING

SEVERE WEATHER FORECASTING

SUPPORT OF TROPOSPHERIC PREDICTION AND AIR/SEA INTERACTION PROCESSES

OPTIMUM TRACK SHIP ROUTING

RADAR RANGE PREDICTION

DRIVING FORCE INPUTS TO SEA/SWELL, TIDE CURRENT, THERMAL STRUCTURE FORECASTS IN THE OCEANS

TABLE 28. POSSIBLE TRENDS IN FUTURE ENVIRONMENTAL SERVICES COMPUTATIONS IN THE OCEANS

DOMAIN OF INTEREST	APPLICATIONS
SPECTRAL SEA/SWELL ANALYSIS AND PREDICTION	HIGH SEAS WARNINGS, OPTIMUM TRACK SHIP ROUTING, SURF PREDICTION, SUBMARINE DETECTABILITY, REPLENISHMENT OF SHIPS, OCEANIC ENGINEERING, ICBM LAUNCH, PORT MANAGEMENT
THERMAL AND SALINITY STRUCTURE ANALYSIS	HYDRODYNAMIC PREDICTION, SOUND RAY TRACING
HYDRODYNAMIC PREDICTION	THERMAL STRUCTURE, CURRENTS, TIDES, STORM SURGES, SEARCH AND RESCUE, SUB-SURFACE TURBULENCE PREDICTION
HYDRODYNAMIC/DIFFUSION PREDICTION	POLLUTION CONTROL
ICE PREDICTION	ICEBERG WARNINGS, POLAR PACK THICKNESS/ CONCENTRATIONS
SOUND PROPAGATION MAPPING	PRO/ANTI-SUBMARINE
AIR/SEA HEAT EXCHANGE	OCEAN WEATHER PREDICTION, EXTENDED TROPOSPHERIC PREDICTION
AMBIENT NOISE MAPPING	PRO/ANTI-SUBMARINE, SHIPPING CONTROL

TABLE 29. POSSIBLE TRENDS IN FUTURE DOD ENVIRONMENTAL SERVICES COMPUTATIONS IN STRATO-, MESO-, AND THERMOSPHERE

DOMAIN OF INTEREST	APPLICATIONS
STRATO-, MESO-, AND THERMOSPHERE ANALYSES AND PROGNOSES	
• GLOBAL MODELLING OF THE UPPER ATMOSPHERE	BALLISTIC WEAPON TARGETING RADIO PROPAGATION
• PROGNOSES UP TO 24 HOURS	SATELLITE DRAG SYSTEMS
• USES OF SATELLITE TECHNIQUES MEASURING ATMOSPHERIC EMISSION (STRATOSPHERE), ATMOSPHERIC ABSORPTION OF SOLAR RADIATION (MESOSPHERE AND THERMOSPHERE), AND SOLAR RADIATION MONITORING (SOLRAD HI)	TAILORED PRODUCTS FOR PARTICLE AND RADIATION PREDICTIONS FOR CUSTOMERS IN THE NEAR EARTH ENVIRONMENT. SUPPORT TO MAN IN SPACE MISSILE DISCRIMINATION

IV. POSTULATED NEW DATA SOURCES

A question asked in the course of this development is what environmental sensor systems may the DoD utilize to meet military needs in 1975. Particular attention should be given to meeting needs that are currently unmet as these needs are likely to compel the utilization of the new techniques. As a chief source of new data, the potential of satellite systems and of ocean data collection systems is examined. To begin the study, we asked what are the exemplar satellite configurations possible in 1975. These are listed in Table 30. With detail elaborated in Appendix D of this study, the satellites have the characteristics shown in Table 30 with measurement data rate of output that vary from 1 to 10^7 bits per second. They are satellites which operate in orbits from low altitudes to orbits at 20 earth radii. To derive data from the hypothetically optimal system for global coverage, ground stations are required. As intermediate links for the data, communication relay satellites are also required. The global system coverage of the geosynchronous satellites used for data input and for communication is shown in Fig. 25. The ground stations necessary for readout of the optimal satellites are listed in Table 31, which show the number of 30-foot equivalent antennas which each site must have and the data rate of the information which it will handle. The number of an-antennas required for each of six sites varies from 2 to 7 and the data rate varies from 10^3 to 10^8 bits sec^{-1}.

It is then appropriate to inquire as to how many of these exemplar satellites may be expected to exist in 1975. There are plans for a number of satellites which in effect accomplish the functions in varying degrees. Those satellites programmed prior to 1975 are

TABLE 30. EXEMPLAR SATELLITE CONFIGURATIONS, 1975

VEHICLE	DATA TYPE	ORBIT		NUMBER REQUIRED	PAYLOAD***			MEASUREMENT DATA RATE (BIT SEC^{-1})
		INCLINATION	ALTITUDE (km)		WEIGHT (lb)	POWER (watts)	VOLUME (ft^3)	
SATELLITE A	PHOTOGRAPHIC & EMISSION	POLAR	1,100	4	248	254	15	$1.5(10)^5$
SATELLITE B	ABSORPTION	LOW INCLINATION	700	4	40	20	4	$1.7(10)^3$
SATELLITE C*	PHOTOGRAPHIC & EMISSION	GEOSYN-CHRONOUS EQUATORIAL	35,800	4	170	230	8	$2.5(10)^7$
SATELLITE D	SOLAR MON.	EQUATORIAL	128,000 (20 Re)	3	225	35	10	1.4
OCEAN DATA COLLEC-TION PLATFORMS	OCEAN & MET. DATA	GRID OF 380 km SPACING	STATIONS IN OCEANS	3500	(REF: ODESSA-TICUS, SHIPS, ETC.)			3500 x $2.5(10)^2$
SATELLITE E	COMM. RELAY OF DATA OF [SATELLITES A+B+C+D, +(DCP)] TO SINGLE GROUND STATION	GEOSYN-CHRONOUS EQUATORIAL	35,800	2	(REF: INTELSAT IV - 12 REPEATERS OF 40 MH_z BAND WIDTH)			$2.6(10)^7$

*FUNCTION OF SATELLITES C & E MAY BE COMBINED IN ONE SATELLITE SPACECRAFT TYPE C & E

**DATE RATE TO A SINGLE GROUND STATION

***SUM OF CONTAINED INSTRUMENTS

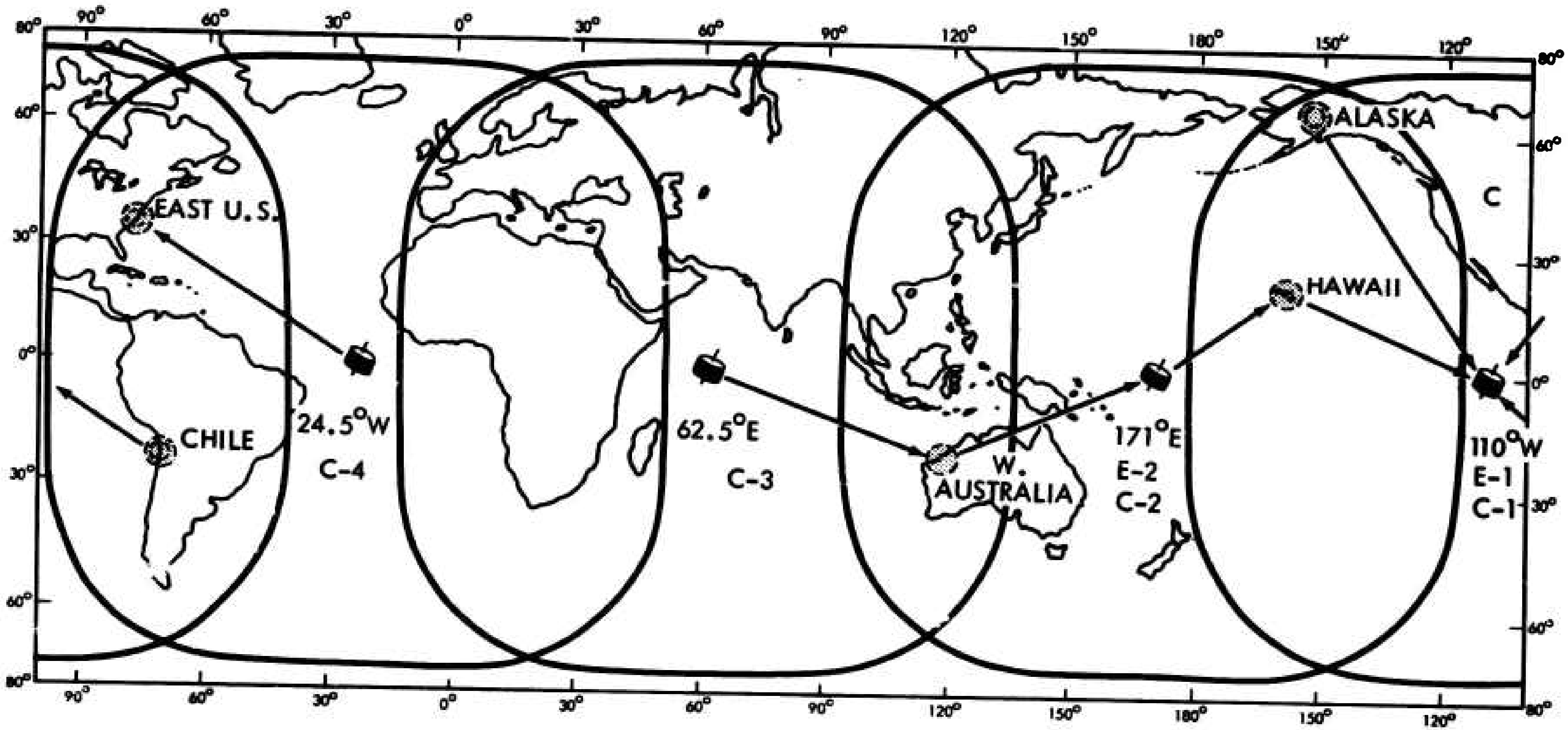


FIGURE 25. Global System Coverage--Satellites C&E

listed in Table 32. Not all the satellites have the exemplar instrument configuration; not all the satellites are programmed to give the same global coverage. The final column in Table 32 lists a measure of the total effectiveness. Approximately 70 percent of the effectiveness of the optimum satellites will be provided by satellites already programmed by civil agencies in 1975.

TABLE 31. GROUND STATIONS FOR SATELLITE READOUT

SITES	COMM. WITH SATELLITES	NO. OF 30'EQ. ANTENNAS	DATA RATE (BIT SEC^{-1})
SITE C (CONUS)	C-1 D-1 E-1	3	$1.1 (10)^8$
EAST U.S.	2 OF SAT A 2 OF SAT B C-4 D-3 E-1	7	$1.1 (10)^8$
ALASKA	4 SAT A	4	$6 (10)^5$
HAWAII	2 SAT B C-2 E-2	4	$5 (10)^7$
CHILE	2 OF SAT B	2	$3.4 (10)^3$
W. AUSTRALIA	C-3 D-2	2	$2.5 (10)^7$

Two important elements of this civil system, however, are outside U.S. control. Here again there may be a dependence on international cooperation.

One of the types, Satellite D or SOLRAD HI, is fully planned for implementation. One of them, Satellite E or INTELSAT 4, can be satisfied by the technical capabilities of INTELSAT 4. However,

since INTELSAT 4 is primarily designed for civil communications, it may not be available to be dedicated for military purposes.

TABLE 32. EXEMPLAR SATELLITES VERSUS PROGRAMMED SATELLITES, 1975-80

Exemplar System							Programmed for 1975			
Satellite	Data Type	Orbit Inclin.	Orbit Altitude (km)	Number in Orbit	Measurement Data Rate (Bit Sec^{-1})	NASA/NOAA/DoD	Number Programmed	Fractional Capability of Exemplar Instruments*	Total Fractional Capability of Exemplar System*
A	Photographic	Polar	1100	4	$1.5x10^5$	NIMBUS I	No Photo After 1972	0	0
	Emission					NIMBUS D(70) NIMBUS E(73) TIROS M(70) TIROS N(75)	2	0.7	0.3
B	Absorption	Low Inc.	700	4	$1.7x10^3$	Not Planned	0	0	0
C	Photographic	Equat.	35,800	4	$2.5x10^7$	SMS/GOES/FR/JAP	2 + 1 + 1	0.7	0.7
	Emission					None		0	0
	DCP Interr.					SMS/GOES/FR/JAP	2 + 1 + 1	1.0	1.0
D	Solar Flux	Equat.	128,000	3	1.4	SOLRAD HI	3	1.0	1.0
E	Communications Relay	Equat.	35,800	2	$2.6x10^7$	INTELSAT IV	23	1.0	0.7

*Ratio (instruments on board or in orbit/instruments of exemplar satellite).

A similar approach was used in estimating the requirements for ocean data collection platforms. An exemplar buoy configuration for the period 1975 to 1980 is described in Table 33. This buoy system requires 3500 buoys spaced at about 350 kilometers spacing with instruments measuring down to 300 meters and with data sampled at about 6-minute intervals readout by satellite at 90-minute intervals.

The exemplar buoy uses a hull 7 feet diameter and 16½ inches in height moored by taut moor to Stimson and Danforth anchors. Such a hull and mooring has been demonstrated by NOAA and the Coast Guard. The instrumentation which is required for the computational data may be carried on such a hull and is listed in Table 33. These instruments have been separately demonstrated in the Satellite Interrogated Environmental Buoy and in the ODESSA TICUS Buoys. The NOAA GOES satellite in 1972 is designed to interrogate 3500 data collection platforms of this kind.

TABLE 33. EXEMPLAR BUOY CONFIGURATION, 1975-80

SYSTEM: 3500 buoys; 350 km spacing; 0 - 300 m depth; 6 min. sample period; total info. rate $9(10)^5$ bits sec^{-1}

HULL: 7 ft dia; 16½ in. height; 330 lb weight equipped; maximum mooring depth 18,000 ft at 1:1 scope by piano wire and nylon to Stimson and Danforth anchors

INSTRUMENTS:	RANGE	ALLOWABLE UNCERTAINTY	DEMONSTRATION
Air Sensors			
Wind Velocity	3 - 120 kt/360°	± 5 kt/± 20°	
Air Temperature	-30°C to 45°C	± 1°C	
Air Pressure	900 - 1050 mb	± 2 mb	S.I.E.B
			($7000 ea) (3 ea in 1967)
Water Sensors			OPLE (1970) to GOES (Sat C) for 3500 DCP
			IRLS (1971) to NIMBUS (Sat A)
At Level 0:			
Current Velocity	0.05 - 7 kt/360°	± 0.1 kt/5°	
Sea Temperature	0 - 40°C	± 0.2°	
Salinity	0 - 40 ppt	± 0.15%	
At Level 1:			
Current Velocity	0.05 - 7/360°	± 0.1 kt/± 5°	ODESSA - TICUS
Sea Temperature	0 - 40°C	± 0.2°	(10 ea in 1967) ($20,000 ea)
Salinity	0 - 40 ppt	± 0.15%	(0 - 100 m depth)
Pressure	0 - 500 lb in^{-2}	± 5 lb in^{-2}	
At Levels 2, 3, 4, and 5:			
(Same as Level 1)			

A comparison of the exemplar configuration of data collection platforms which have been described above and those existing in 1970 and planned to exist in 1975 to 1980 is shown in Table 34. At present there are about 200 bits per second of data available on the oceans derived chiefly from ships of opportunity. It is projected in 1975 to 1980 that this number will be about 10^4 bits per second. This number is only 1 percent of that possible from a 3500-buoy system, however, it is still an impressive amount of data for use as a basis for modelling ocean geophysics.

TABLE 34. OCEAN DATA COLLECTION PLATFORMS OF 1970 AND 1975-80

TIME	PLATFORM	NO.	INSTRUMENT*	TELEMETRY SAMPLE PERIOD (HRS)	TELEMETRY DATA RATE (BITS/SEC)
PRESENT 1970	SHIPS OF OPPORTUNITY	600 150	METEOROLOGIC SXBT	6 12	$2(10)^2$ 2
	RECCO AIRCRAFT	10 5	AXBT ART	0.5 0.1	1 2
	COASTAL STATIONS	200	METEOROLOGIC	6	5
	BUOYS	10	METEOROLOGIC OCEAN	1-6	5
PROJECTED 1975 - 80	SHIPS OF OPPORTUNITY**	1500 600	METEOROLOGIC SXBT	1 6	$5(10)^2$ $5(10)^2$
	RECCO AIRCRAFT	40	AXBT ART WAVE RECORD	0.1	$2(10)^2$
	COASTAL STATIONS	400	METEOROLOGIC	3	$2(10)^2$
	BUOYS***	35	METEOROLOGIC OCEAN	0.1-0.2	$9(10)^3$
EXEMPLAR 1975-80	BUOYS***	3500	METEOROLOGIC OCEAN	0.1-0.2	$9(10)^5$

*SXBT, SHIPS EXPERIMENTAL BATHYTHERMOGRAPH; AXBT, AIRDROPPED EXPERIMENTAL BATHYTHERMOGRAPH; ART, AUTOMATIC RECORDING THERMOGRAPH.
**PARAMETERS: STANDARD METEOROLOGICAL PLUS OCEAN TEMPERATURE, SALINITY, CURRENTS, TIDES, SEA STATE, AMBIENT NOISE.
***SATELLITE INTERROGATION AND RELAY.

V. COMPUTATIONAL REQUIREMENTS

As has been said earlier, there has also been a breakthrough in the computer technology. A computer which has been delivered today represents a capacity that is an order of magnitude more capable, than the totality of computers that are in existence at Fleet Numerical Weather Central and at Global Weather Central.

Shown in Table 35 are characteristics of computers expected to be available in 1975 shown in comparison with the CDC 6600. Equipments now in use at Fleet Numerical Weather Central approximate 1.4 of the capability of the CDC 6600 and those at Air Force Global Weather Central approximate 1.6 that capacity. The Class 4 computers listed in Table 35 represent a gain by a factor of 30 in improvement of capability over that of the CDC 6600. The costs of the new brand of Class 4 computers are 2 to 3 times the cost of the CDC 6600. Companion to the increase of computer capacity is the increase in capability of storage devices. Archival storage devices are listed in Table 36. Powerful central processing units require storage devices of this large capacity.

In order to assess the computer and memory needs in this study an estimate was made of the computer capacity required for the computation of the large global models on which the military applications may be based in 1975. These models include a global model of the troposphere using the primitive equations comparable to those described by Kesel, 1970; the ocean troposphere model similar to that described by Bryan and Manabe, 1969; and the troposphere, stratosphere, mesosphere, thermosphere model described in detail in Appendix E to this study. The characteristics of these environmental models as they affect the computation are tabulated in Table 37. The global troposphere

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model requires 8.3 seconds of CDC 6600 time per second of chronologic time, the oceans model 11.3 seconds per second, and the stratosphere, troposphere, thermosphere model 10 seconds per second.

TABLE 35. COMPUTER SPEED COMPARISONS AND COST ESTIMATES

Class	Manufacturer	Computer	Range of Ratio Normalized to CDC 6600	Ratio As Used in Report	Cost Range (In millions)	Cost Used* In Report (In millions)
1	Univac	1108	0.3 - 0.6	0.4	2 - 4	3
	Control Data	6500	0.5 - 0.8	0.7		
	Univac	1108 MP	0.5 - 0.9	0.7		
2	Control Data	6600	1	1	4 - 6	5
	Univac	1110				
3	Control Data	7600	3 - 8	5	7 - 10	8
	IBM	360/195	5 - 8			
4	Control Data	STAR	22 - 31	30	10 - 20	12
	Texas Inst.	ASC-4X	25 - 35			
	Burroughs	ILLIAC IV	27 - 38			

*Based on production quantities.

The computer and memory requirements necessary for the solution of the global models and of the applications which have been recognized are summed in totality in Table 38. Inspection of Table 38 shows that the total requirement, with allowance for program maintenance and development and for preventive maintenance and dead time, is 112 seconds of CDC 6600 per second of chronologic time. This represents a requirement for the equivalent of 112 CDC 6600 equipments. The main memory which will be required is of the order of one million words and of the order of a billion words of rotating memory. The requirement for archival storage for purpose of climatology is of the order of a trillion words per month. The material included in Table 39 describes for the troposphere alone the projected computer requirements. Capability for 55 seconds per second is required involving two Class 4 machines and two Class 3 machines if the task is undertaken without

TABLE 36. ARCHIVAL STORAGE DEVICES

MANUFACTURER	RECORDING TECHNOLOGY	ACCESS TIME	STORAGE CAPACITY	AVAILABILITY	COST RANGE, $ MILLION	COST USED IN REPORT, $ MILLION
IBM	Photographic (Film Chip)	5 - 10 sec	$3 \times 10^{11} - 10^{12}$	5 Installed (not in current production).	0.8 - 1.2	1.0
Precision Instruments	Laser (Mylar Strip)	max. 10 sec	10 - 10	1st Deliveries in 1971.	0.4 - 1.6	
Ampex	Video Magnetic (Mylar Reels)	10 sec	$10^{12} - 3 \times 10^{12}$	Demonstration model built. Deliveries in 1972.	1.0 - 3.0	
Grumman	Magnetic (Cassette Reels)	1 to 10 sec	$10^{11} - 10^{12}$	Under devel. for Rome ADC. Possible in 1972.	0.3 - 1.2	

TABLE 37. 1975 ENVIRONMENTAL MODELS

(1) Model	(2) Model Subdivisions	(3) Number Horizontal Points	(4) Number Vertical Points	(5) Total Points	(6) Time Step	(7) Prognosis Period	(8) Number Time Steps	(9) Total Point Calculations (5) x (8)	(10) Estimated CDC 6600 Time Per Point	(11) Total 6600 Time Per Run	(12) Number Of Runs Per Day	(13) Total 6600 Time Per Day	(14) Seconds Per Second
Tropo-sphere	(None)	32000	10	320,000	5 min	36 hr	432	138×10^6	1.3 ms	50 hr	4	200 hr	8.3
Ocean/Tropo-sphere	Fine Mesh	8000	5	40,000	15 sec	24 hr	5760	230.4×10^6	1.0 ms	68 hr	4	272 hr	11.3
	Coarse Mesh	24000	5	120,000	10 min	24 hr	144	17.3×10^6	1.0 ms				
Tropo/Strato/Meso/Thermo-sphere	U,V,T,P,n_i	8000	33	264,000	10 min	36 hr	216	57×10^6	1.0 ms	60 hr	4	240 hr	10
	Radiation, etc.	8000	28	224,000	2 hr	36 hr	18	4×10^6	40 ms				

TABLE 38. 1975 COMPUTER AND MEMORY** REQUIREMENTS

(1) DOMAIN OF INTEREST	(2) MINUTES PER RUN*	(3) RUNS PER DAY	(4) HOURS PER DAY*	(5) SECONDS PER SECOND*	(6) APPROPRIATE COMPUTER	(7) OPTIMUM MAIN MEMORY	(8) ROTATING MEMORY	(9) MAGNETIC TAPE PER RUN	(10) ARCHIVAL STORAGE PER MONTH
TROPOSPHERE									
1. Global Primitive Eq. & Window Models	3000	4	200	8.3	Class 4	5×10^7	8×10^8	4×10^9	2×10^{10}
2. FNWC Applications (1970)	1170	4	78	3.3	Class 3	2.5×10^7	2×10^9	-	-
3. AFGWC Applications (1970)	1200	4	80	3.3	Class 3	2.5×10^7	2×10^9	-	-
OCEANS									
1. Global Oceans Model	4100	4	272	11.3	Class 4	5×10^7	5×10^8	3×10^9	1×10^{10}
2. Sound Propagation	36	500	300	12.5	Class 4	5×10^7	1×10^8	-	-
3. Other FNWC Applications (1970)	60	4	4	.2	Class 1	1.2×10^7	1×10^9	-	-
STRATO-MESO-THERMOSPHERE									
1. Global S-M-T Model	3600	4	240	10.0	Class 4	1×10^8	6×10^8	2×10^9	1×10^{10}
2. Radio Propagation	3	1000	50	2.1	Class 3	2.5×10^7	1×10^8	-	-
3. Satellite Drag	.01	5×10^4	8	.3	Class 1	1.2×10^7	1×10^8	-	-
4. Solar Disturbance Prediction	-	-	-	.01	-	-	-	-	-
DATA COLLECTION AND PRE-ANALYSIS FOR ALL OF ABOVE									
1. Awn (1970 Capacity)	30	2	1	.04	Class 1	1.2×10^7	5×10^8	-	-
2. Satellite Data - Tropo(Satellites A & C)	-	-	488	20.3	Class 4	2.5×10^7	1×10^{10}	-	-
3. Satellite Data - S-M-T(Satellites B & D)	-	-	-	.02	Class 1	1.2×10^7	1×10^9	-	-
4. Buoy Data (Oceans) (3500 via Satellite)	-	-	10	.4	Class 3	1.2×10^7	2×10^9	-	-
SUB-TOTAL	-	-	(1731)	(72.1)	-	-	-	-	(4×10^{10})
SUPPORT***									
1. Research & Development (25% of above total)	-	-	433	18.0	As Required	5×10^7	8×10^8	As Required	-
SUB-TOTAL	-	-	(2164)	(90.1)	-	-	-	-	-
2. Preventive Maintenance & Downtime (Estimated) (25% of above total)	-	-	541	22.5	-	-	-	-	-
TOTAL	-	-	(2705)	(112.6)	(3.7 Class 4)	-	-	-	(4×10^{10})

*Equivalent CDC 6600 time.

**All memory requirements are stated in bits. For this table, a word was estimated at 50 bits.

***10% of total or 12½% of sub-total for each sub-category.

also undertaking the oceanic or stratosphere, mesosphere, thermosphere tasks. Machines required for the troposphere problems include two Class 4, two Class 3, and 1 Class 1. For a needed capacity of 56 seconds per second of computer computation, these machines aggregate 70.8 seconds per second of computer capacity.

TABLE 39. 1975 PROJECTED COMPUTER REQUIREMENTS FOR TROPOSPHERE

DOMAIN OF INTEREST	SECONDS PER SECOND*	APPROPRIATE COMPUTER FOR PROGRAM ALONE	APPROPRIATE COMPUTER CAPACITY (SEC SEC^{-1})
TROPOSPHERE			
GLOBAL PRIMITIVE EQ. & WINDOW MODELS	8.3	CLASS 4	30.0
FNWC APPLICATIONS (1970)	3.3	CLASS 3	5.0
AFGWC APPLICATIONS (1970)	3.3	CLASS 3	5.0
DATA COLLECTION AND PRE-ANALYSIS FOR ALL OF ABOVE			
AWN (1970 CAPACITY)	0.04	CLASS 1	0.4
SATELLITE DATA - TROPO	20.3	CLASS 4 DEDICATED	30.0
BUOY DATA - OCEANS	0.1	CLASS 1	0.4
PROGRAM DEVELOPMENT	8.9	AS REQ	
EQUIPMENT MAINTENANCE	11.0		
TOTAL	55.2		70.8

*SECONDS OF CDC 6600 OPERATION PER SECOND OF CHRONOLOGIC TIME OF NEEDED DATA PROCESSING OR CPU TIME NORMALIZED TO TIME NEEDED BY CDC 6600

Table 40 shows the projected computer requirements for ocean studies in 1975 and 1980. For the ocean applications, equipment capable of accomplishing 38.1 seconds per second equivalent of CDC 6600 are required for the global oceans model, the sound propagation mapping, other Fleet Numerical Weather Central applications as currently accomplished and the pre-analysis of data from a system of 3500 ocean buoys. If these programs are done alone, two Class 4 and two Class 1 equipments will be required, having a total capability of 60.8 seconds per second.

TABLE 40. 1975 PROJECTED COMPUTER REQUIREMENTS FOR OCEANS

DOMAIN OF INTEREST	SECONDS PER SECOND	APPROPRIATE COMPUTER FOR PROGRAM ALONE	CAPACITY ($SEC\ SEC^{-1}$)
OCEANS			
GLOBAL OCEANS MODEL	11.3	CLASS 4	30.0
SOUND PROPAGATION MAPPING	12.5	CLASS 4 DEDICATED	30.0
OTHER FNWC APPLICATIONS (1970)	.2	CLASS 1	0.4
DATA COLLECTION AND PRE-ANALYSIS FOR ALL OF ABOVE			
BUOY DATA (OCEANS)	0.3	CLASS 1 DEDICATED	
PROGRAM DEVELOPMENT	6.1	AS REQ	
EQUIPMENT MAINTENANCE	7.6		
TOTAL	38.0		60.8

For the 1975 projected computer requirements for the stratosphere, mesosphere, thermosphere, as outlined in Table 41, 19.4 seconds per second of computer capability are required for the accomplishment of the Global's S-M-T model radio propagations, satellite drag, and solar disturbance predictions, as well as the pre-analysis of satellite data relating to the stratosphere, mesosphere, thermosphere. If these tasks are done by a computer without relation to other domains of interest, one Class 4 and one Class 3 machines are required having a total capability of 35 seconds per second.

TABLE 41. 1975 PROJECTED COMPUTER REQUIREMENTS FOR STRATO-, MESO-, AND THERMOSPHERE

DOMAIN OF INTEREST	SECONDS PER SECOND	APPROPRIATE COMPUTER FOR PROGRAM ALONE	APPROPRIATE COMPUTER CAPACITY SEC SEC^{-1}
STRATO-MESO-THERMOSPHERE			
GLOBAL S-M-T MODEL	10.0	CLASS 4	30.0
RADIO PROPAGATION	2.1	CLASS 3	5.0
SATELLITE DRAG	.3		
SOLAR DISTURBANCE PREDICTION	.01		
DATA COLLECTION AND PRE-ANALYSIS FOR ALL OF ABOVE			
SATELLITE DATA - S-M-T	0.02		
PROGRAM DEVELOPMENT	3.1	AS REQ	
EQUIPMENT MAINTENANCE	3.9		
TOTAL	19.4		35.0

VI. ALTERNATIVE OPTIONS

To meet the basic objectives of this study it is now necessary to consider the DoD alternatives involved in the possible collocation and/or consolidation of the DoD environmental services support centers. The number of possible alternatives available to DoD is large; however, the spectral range of possibilities may perhaps be defined in terms of four basic options, herein called Options 0, 1, 2, and 3, the scheme of which is given in Fig. 26. As the matrix shown in the figure indicates, the four basic options considered in detail describe the several combinations of separate or collocated installations. Within the simple statement of the four options, there are, however, a number of choices to be made. The choices for this study have been made with an eye to making them realizable in terms of current practical operational constraints as well as to making them as inexpensive as possible (see Table 42 for detail of Options 0, 1, 2, and 3).

	AF & Navy Separate	AF & Navy Collocated
Inadequate Meeting of Stated Needs	Option 0	Option 1
Meeting Stated Needs	Option 2	Option 3

FIGURE 26. DoD Options for 1975-80

Option 0 is a baseline alternative wherein no change is made to either the present operations at the Fleet Numerical Weather Central Monterey, or the AFGWC at Omaha and no provision is made for meeting either presently unmet needs or 1975 needs.

TABLE 42. ALTERNATIVE OPTIONS

OPTION		
0	AT MONTEREY 1970 NAVY OPERATIONS IN 1975	AT OMAHA 1970 AF OPERATIONS IN 1975
1		AT OMAHA PRESENT NAVY AND AF OPERATIONS 1970-1975
2	AT MONTEREY NAVY OPERATIONS IN 1975 • TROPOSPHERE ANALYSIS, PROG. AND APPLICATIONS • OCEAN ANALYSIS, PROGNOSIS AND APPLICATIONS. REDUCTION OF BUOY DATA RECEIVED FROM OMAHA	AT OMAHA AF OPERATIONS IN 1975 • TROPOSPHERE ANALYSIS, PROGNOSES, APPLICATIONS • S-M-T ANALYSES, PROGNOSES AND APPLICATIONS • RECEPTION AND REDUCTION OF SATELLITE DATA WITH TRANSMISSION OF FIELD DATA BY LANDLINE TO MONTEREY
3	AT SITE C COLLOCATED/CONSOLIDATED OPERATION FOR ANALYSIS, PROGNOSIS AND CLIM. STORAGE--SERVICE SPECIALIZATION FOR APPLICATIONS • TROPOSPHERE ANALYSIS, PROGNOSIS, APPLICATIONS AND CLIM. STORAGE WITH REQUIRED SATELLITE DATA RECEPTION AND REDUCTION • OCEAN ANALYSIS, PROGNOSIS, APPLICATIONS AND CLIM. STORAGE WITH REQUIRED BUOY DATA RECEPTION AND REDUCTION • S-M-T ANALYSIS, PROGNOSIS AND APPLICATIONS WITH REQUIRED SAT. RECEPTION AND REDUCTION.	

AT MONTEREY--INTERIM TROPO. AND OCEANIC ANALYSIS, PROG. AND APPLICATIONS (CEASING IN 1978)

AT OMAHA--INTERIM TROPO. ANALYSIS, PROG. AND APPLICATIONS (CEASING IN 1978)

Option 1 considers the possibility of a combined Navy/Air Force operations at Omaha with no expansion of capability necessary to meet either presently unmet needs or 1975 needs.

Option 2 considers separate Navy and Air Force facilities with the expanded capability necessary to meet 1975 requirements. Both centers provide the troposphere analysis required by their respective Services; ocean buoy data via satellite are received at Omaha (if Omaha is selected as the site for the satellite data processing function) and transmitted by landline to Monterey for reduction, while satellite-obtained data on the troposphere, stratosphere, mesosphere, and thermosphere are received and processed at Omaha.

Option 3 considers an inter-Service joint operation of an environmental services support center, equipped to meet 1975 requirements, located at a site not selected by the study but separate to permit interim operation of both of the present centers until the new site is fully operational.

The major equipment complement for Options 0 and 1 is just that equipment which is used today at FNWC and AFGWC. That equipment is summarized principally in terms of operational capability in Table 43 and consists of 2 CDC 6500s equipments and 4 Univac 1108s with required memory capacity and other peripheral equipments.

TABLE 43. MAJOR EQUIPMENT COMPLEMENT FOR OPTIONS 0, 1

OPTION	SECONDS/ SECOND (CDC 6600)	COMPUTER AND STORAGE COMPLEMENT
OPTION 0		
SITE: MONTEREY	1.4	2 - CDC 6500
SITE: OMAHA	1.6	4 - SRU 1108
OPTION 1		
SITE: OMAHA	3.0	2 - CDC 6500
		4 - SRU 1108

The time-phasing of a plan for realizing Option 1, which involves the relocation of Fleet Numerical Weather Central from Monterey to Omaha, is shown in Fig. 27. This plan involves the use of leased CDC 6500 equipments, one located temporarily at Monterey and the other temporarily at Omaha to permit the transition of Navy-owned equipments from Monterey to Omaha. The details of the move which are shown in Fig. 27 are considered pragmatically realizable. The chief time delay is that for the preparation of the site at Omaha. The Navy personnel involved in the move of Option 1 are listed in Table 44. The requirement for Navy personnel at the end of the move is reduced by 11 people. The transition period involves the use of nearly 50 extra people in FY 1973 & FY 1974 in order that the overlap may be complete. The Air Force personnel involved in the exercise of Option 1 is unchanged from that of Option 0 and the current practice. Table 45 shows the cost estimates for Option 1.

In the event that a decision is made to satisfy the military needs, including many currently unmet, with the technology which may be available in 1975, either Options 2 or 3 may be chosen.

Option 2 provides for separate operation by the Navy and Air Force at Monterey and Omaha with the Fleet Numerical Weather Central and Global Weather Central buildup as the new needs require. The major equipment complement is listed in Table 46. It should be noted that this equipment complement, since it involves machines of a specified competence, provides 67.1 seconds per second at Monterey to meet a need defined in this report as 56.3 seconds per second and 93.4 seconds per second of equipment at Omaha to meet a need defined in this report as 69.4 seconds per second. The differences represent reserve for growth which has not been specified in this report but which surely can be expected.

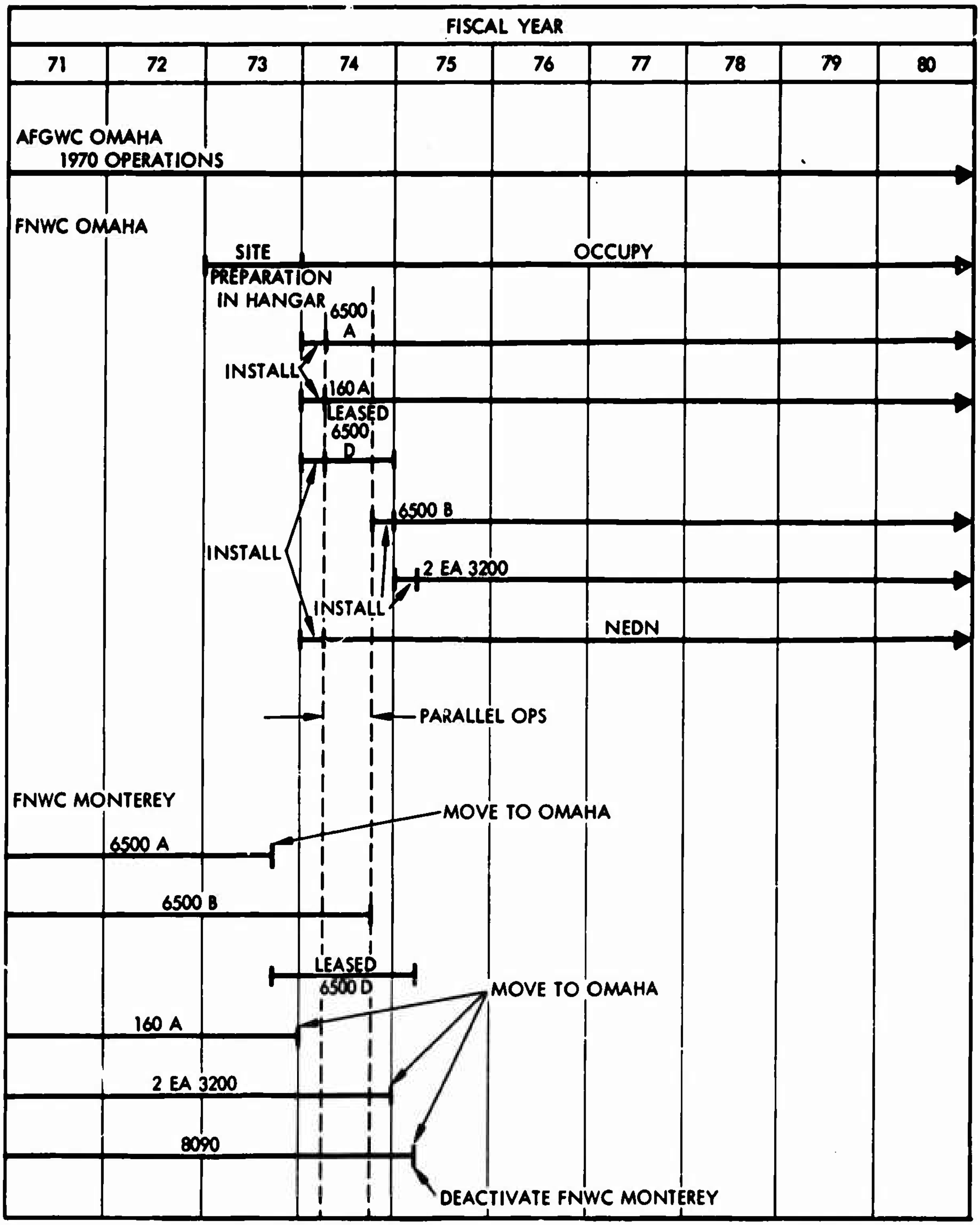

FIGURE 27. Time-Phased Plan for Option 1

TABLE 44. PERSONNEL FOR OPTION 1

	FY 71	FY 72	FY 73	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79	FY 80
FNWC Monterey Equipment	2_1*	2_1	2_1	2_1	0	0	0	0	0	0
A. Operators	39	39	39	39	0	0	0	0	0	0
B. Maintenance & Engineering	22	22	22	22	0	0	0	0	0	0
C. Systems Programming	7	7	7	7	0	0	0	0	0	0
D. Applications Programming	55	55	55	55	0	0	0	0	0	0
E. Administration	15	15	15	15	0	0	0	0	0	0
Subtotal	138	138	138	138	0	0	0	0	0	0
F. Meteorology/Oceanography/ Quality Control	5	5	5	5	0	0	0	0	0	0
TOTAL-FNWC MONTEREY	143	143	143	143	0	0	0	0	0	0
FNWC Omaha Equipment	0	0	0	2_1	2_1	2_1	2_1	2_1	2_1	2_1
A. Operators	0	0	0	40	40	40	40	40	40	40
B. Maintenance & Engineering	0	0	12	22	22	22	22	22	22	22
C. Systems Programming	0	0	4	7	7	7	7	7	7	7
D. Applications Programming	0	0	27	55	45	45	45	45	45	45
E. Administration	0	0	5	14	14	14	14	14	14	14
Subtotal	0	0	48	138	128	128	128	128	128	128
F. Meteorology/Oceanography/ Quality Control	0	0	0	5	4	4	4	4	4	4
TOTAL-FNWC OMAHA	0	0	48	143	132	132	132	132	132	132
AFGWC Omaha Equipment	4_1	4_1	4_1	4_1	4_1	4_1	4_1	4_1	4_1	4_1
A. Operators	95	95	95	95	95	95	95	95	95	95
B. Maintenance & Engineering	11	11	11	11	11	11	11	11	11	11
C. Systems Programming	30	30	30	30	30	30	30	30	30	30
D. Applications Programming	78	78	78	78	68	68	68	68	68	68
E. Administration	50	50	50	50	48	48	48	48	48	48
Subtotal	264	264	264	264	252	252	252	252	252	252
F. Meteorology/Oceanography/ Quality Control	228	228	228	228	203	203	203	203	203	203
TOTAL-AFGWC OMAHA	492	492	492	492	455	455	455	455	455	455
TOTAL OPTION 1	635	635	683	778	635	587	587	587	587	587

*Refers to number and class of equipment, i.e., 2_1 is two Class 1 computers.

TABLE 45. OPTION 1 COSTS FOR DATA PROCESSING OF DOD ENVIRONMENTAL SUPPORT SYSTEMS OF 1975-80

(Millions of Dollars)

	FY 71	FY 72	FY 73	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79	FY 80	TOTAL (FY 71-80)
FNWC											
Invest. Facilities	-	-	2.3	-	-	-	-	-	-	-	2.3
Invest. EDP Equip.	-	-	-	-	..	-	-	-	-	-	-
Invest. Total	-	-	(2.3)	-	-	-	-	-	-	-	(2.3)
Ops-Communications	.5	.5	.6	.5	.5	.5	.5	.5	.5	.5	5.1
Ops-Pay & Allowances	1.7	1.7	2.3	3.4	1.6	1.6	1.6	1.6	1.6	1.6	18.7
Ops-Non-Pay Costs	.8	.8	1.3	4.5	1.0	.8	.7	.8	.7	.8	12.2
Ops-Total	(3.0)	(3.0)	(4.2)	(8.4)	(3.1)	(2.9)	(2.8)	(2.9)	(2.8)	(2.9)	(36.0)
TOTAL FNWC	(3.0)	(3.0)	(6.5)	(8.4)	(3.1)	(2.9)	(2.8)	(2.9)	(2.8)	(2.9)	(38.3)
AFGWC											
Invest. Facilities	-										
Invest. EDP Equip.	-										
Invest. Total	-	-	-	-	-	-	-	-	-	-	-
Ops-Communications	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	12.0
Ops-Pay & Allowances	5.9	5 9	5.9	5.9	5.5	5.5	5.5	5.5	5.5	5.5	56.6
Ops-Non-Pay Costs	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	17.0
Ops-Total	(8.8)	(8.8)	(8.8)	(8.8)	(8.4)	(8.4)	(8.4)	(8.4)	(8.4)	(8.4)	(85.6)
TOTAL AFGWC	(8.8)	(8.8)	(8.8)	(8.8)	(8.4)	(8.4)	(8.4)	(8 4)	(8.4)	(8.4)	(85.6)
TOTAL OPTION 1	(11.8)	(11.8)	(15.3)	(17.2)	(11.5)	(11.3)	(11.2)	(11.3)	(11.2)	(11.3)	(123.9)

The time plan for Option showin in Fig. 28 continues the building construction already authorized at Fleet Numerical Weather Central located at the Presidio in Monterey. It provides, in addition, a second building to be constructed. In these are involved the equipments currently located at the Navy Post Graduate School which are to be moved to Building 1, and additional equipments, one Class 3 of two Class 4 equipments, which are to be installed on the new site. At AFGWC, preparation of the site for the equipment expansion and the conversion of 4 Univac 1108 equipments to be 2 Univac 1108 (MP) multiprocessors and 2 Univac 1110s are required. The procurement of the Univac 1110 equipments has already begun. In addition to these machines, two Class 4 computers would be initially procured for installation at Omaha to satisfy needs of the troposphere and the strato-, meso-, thermosphere problems. In addition, satellite data processing is required at Omaha which involves the installation of three antennas for ground readout of satellite data and an additional Class 4 equipment for the real-time data reduction of the satellite data stream.

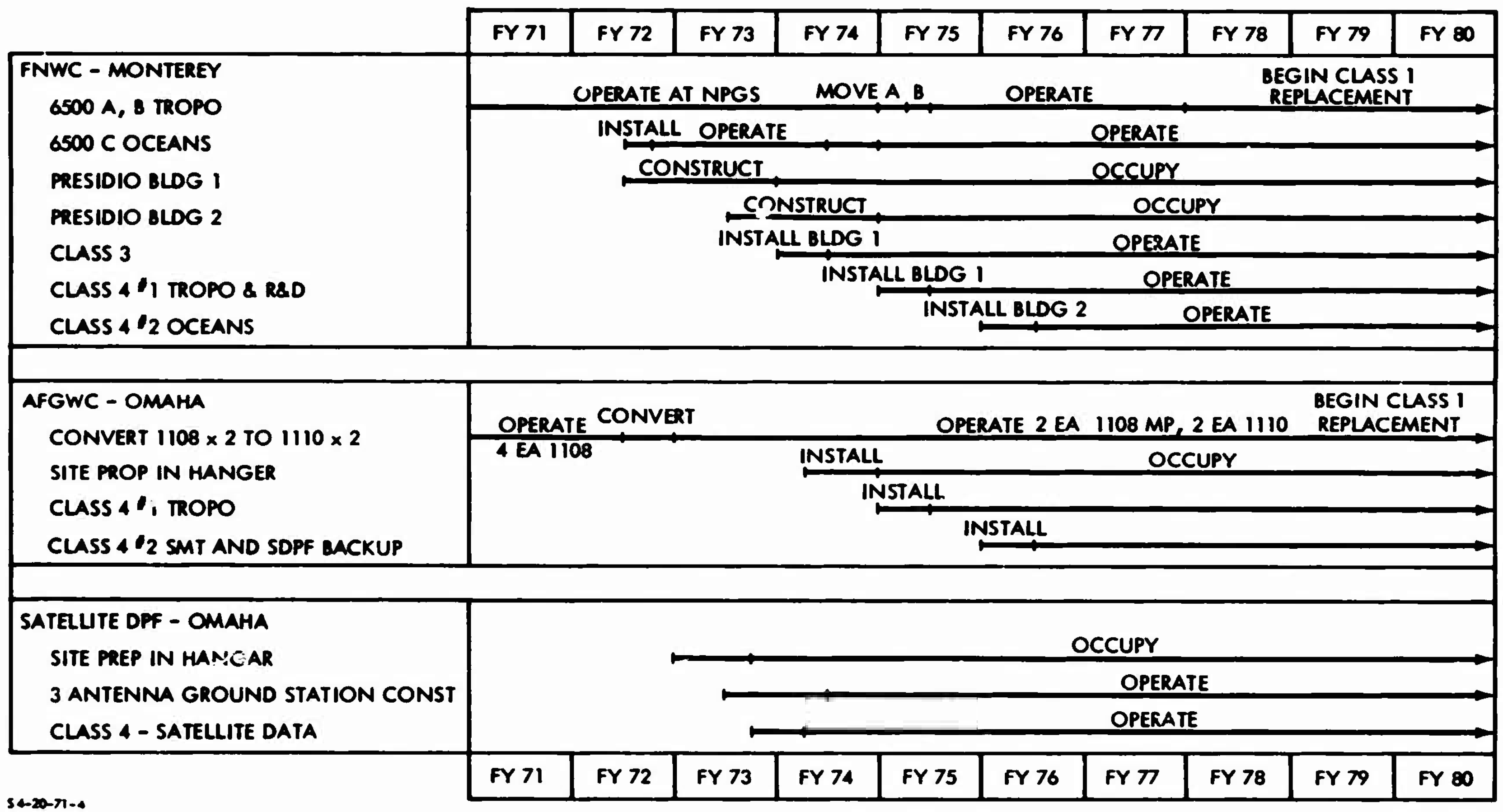

FIGURE 28. Time-Phased Plan for Option 2

TABLE 46. MAJOR EQUIPMENT COMPLEMENT FOR OPTION 2

	PROJECTED NEEDS ($SEC\ SEC^{-1}$)	PROJECTED AVAILABILITY ($SEC\ SEC^{-1}$)	
SITE: MONTEREY			
TROPOSPHERE: MODELS, APPL	11.6	2 CLASS 4	60.0
		1 CLASS 3	5.0
OCEANS: MODELS, APPL, BUOY SYSTEMS	24.4	3 CLASS 1	2.1
		1 CLIMATOLOGY STORE	67.1
STRATO, MESO, THERMOSPHERE	0.01	1 40.8 KILOBAUD TELPAK	
PROGRAM DEVELOPMENT & EQUIPMENT MAINTENANCE	20.3		
	56.3		
SITE: OMAHA (INCLUDING SDPF)			
TROPOSPHERE: MODELS, APPL	11.6	3 CLASS 4	90.0
		2 CLASS 2	2.0
SATELLITE: PHOTO & EMISSION	20.4	2 CLASS 1	1.4
			93.4
STRATO, MESO THERMOSPHERE: MODELS, APPL	12.4	2 10^{10} BIT DISCS	
		1 10^{12} BIT REUSABLE BUFFER	
PROGRAM DEVELOPMENT & EQUIPMENT MAINTENANCE	25.0	1 CLIMATOLOGY STORE	
	69.4		

If satellite data processing were required at Monterey, installation of equipment for the function at Monterey would duplicate that for Omaha given for Fig. 28.

The personnel required for the exercise of Option 2 during each fiscal year from 1971 to 1980 are shown in Table 47. The table subdivides personnel as to types: operators, maintenance engineers, systems programmers, application programmers, and meteorologists and oceanographers used for quality control and as production forecasters and observers. Administrative personnel are also shown. The personnel listed as operators, maintenance engineers, systems programmers, and applications programmers are properly considered as computer personnel whose presence is required for the exploitation of the machine. The

TABLE 47. PERSONNEL FOR OPTION 2

	Actual FY 71	FY 72	FY 73	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79	FY 80
FNWC-Monterey Equipment	2_1^*	3_1	3_1	3_1+1_3	$3_1+1_3+1_4$	$3_1+1_3+2_4$	$3_1+1_3+2_4$	$3_1+1_3+2_4$	$3_1+1_3+2_4$	$3_1+1_3+2_4$
A. Operators	39	59	59	79	99	119	119	119	119	119
B. Maintenance and Engineering	22	28	34	42	48	48	50	50	50	52
C. Systems Programmers	7	7	10	20	23	23	23	23	23	23
D. Appl. Programmers	55	55	75	95	105	105	105	105	105	105
E. Administration	15	18	22	30	35	38	39	39	39	39
Subtotal (EDP)	138	167	200	266	310	333	336	336	336	338
F. Meteor/Ocean Quality Control	5	5	5	10	15	25	30	30	30	30
FNWC Subtotal Before EPRF	143	172	205	276	325	358	366	366	366	368
EPRF R&D	0	0	20	40	60	60	60	60	60	60
FNWC TOTAL	143	172	225	316	385	418	426	426	426	428
FNWC-New (Cumulative) Major Applications	0	0	0	1	2	4	5	5	5	5
AFGWC-OMAHA Equipment	4_1	2_1+2_2	2_1+2_2	2_1+2_2	$2_1+2_2+1_4$	$2_1+2_2+2_4$	$2_1+2_2+2_4$	$2_1+2_2+2_4$	$2_1+2_2+2_4$	$2_1+2_2+2_4$
A. Operators	95	95	95	95	115	135	135	135	135	135
B. Maintenance and Engineering	11	11	11	13	13	13	15	15	15	17
C. Systems Programmers	30	30	30	40	43	43	43	43	43	43
D. Appl. Programmers	78	88	98	108	128	128	128	128	128	128
E. Administration	50	54	64	67	75	81	87	87	87	87
Subtotal (EDP)	264	278	298	323	374	400	408	408	408	410
F. Prod. Forecasters/ Observors	228	228	303	303	328	353	403	403	403	403
AFGWC TOTAL	492	506	601	626	702	753	811	811	811	813
AFGWC-New (Cumulative) Major Applications	0	0	3 (2 already prog.)	3	4	5	7	7	7	7
Satellite DPF-OMAHA Equipment	0	0	14	14	14	14	14	14	14	14
A. Operators	0	0	30	30	30	30	30	30	30	30
C. Systems Programmers	0	30	30	30	30	30	30	30	30	30
D. Applications Prog.	0	10	10	10	10	10	10	10	10	10
E. Administration	0	5	8	12	12	12	12	12	12	12
Subtotal (EDP)	0	45	78	82	82	82	82	82	82	82
B. Satellite Ground Station Operators	0	0	0	30	30	30	30	30	30	30
SDPF TOTAL	0	45	78	112	112	112	112	112	112	112
TOTAL EDP	402	490	576	671	766	815	826	826	826	830
TOTAL OPTION 2	635	723	904	1054	1149	1283	1349	1349	1349	1353

*Refers to number and class of equipment, i.e., 2_1 is two Class 1 computers.

personnel acting the role of quality control and as production forecasters and observers are less firmly related to the computing machinery; in fact, in present practice, the bulk of production forecasters and observers for the Navy are located at Fleet Weather Centrals at Norfolk, Rota, Pearl Harbor, and Guam. The Air Force practice, however, is to concentrate as much of the production forecasting technical talent as close to the principal computing machinery as can be.

Summarizing estimates of personnel requirements, one can see in Table 47 that for Option 2 the total number of data processing personnel is 830; the total personnel located at Fleet Numerical Weather Central is 433; 875 are located at Omaha. Of the personnel located at Omaha, 82 are shown for the satellite data processing function which is operated for the joint interest.

The budgetary cost of undertaking Option 2 is summarized in Table 48. The cost at Monterey may be described as a peak value of $21.5 million in FY 1976, a yearly operating cost after installation of new equipment has been accomplished amounts to $10 million annually, and a total expenditure over ten years ending in FY 1980 of $115.9 million. At Omaha for the Air Force Global Weather Central, exclusive of the satellite data processing function, the costs peak to $25.9 million in FY 1976, reduce to $15.3 million annual cost after the initial investment costs have been made, and result in a total cost for ten years ending in 1980 of $157.5 million. In addition to these costs attributed to the Air Force, a joint cost for the operation of the satellite data processing function in joint interest in Omaha involves a peak cost of $13.9 million in FY 1973 and operation and maintenance costs after investments have been made of $2.8 million per year, and a cost for ten years ending in 1980 of $38.8 million. The grand total cost of Option 2 involves a peak expenditure of $50.2 million in FY 1976 and operation and maintenance cost after investment will have been made of $28 million and a total ten-year cost of $312.1 million.

TABLE 48. OPTION 2 COSTS FOR DATA PROCESSING OF DOD ENVIRONMENTAL SUPPORT SYSTEMS OF 1975-80

(Millions of Dollars)

	FY 71	FY 72	FY 73	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79	FY 80	TOTAL (FY 71-80)
MONTEREY											
Invest. Facilities		3.0	2.0	.3							5.3
Invest. EDP Equip.		3.0	-	8.0	13.0	12.0					36.0
Invest. Total		(6.0)	(2.0)	(8.3)	(13.0)	(12.0)	-	-	-	-	(41.3)
Ops-Communications	.5	.5	.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	8.5
Ops-Pay & Allowances	1.7	2.1	2.7	3.8	4.0	5.0	5.1	5.1	5.1	5.1	39.7
Ops-Non-Pay Costs	.8	1.0	1.2	1.6	2.7	3.5	3.9	3.9	3.9	3.9	26.4
Ops-Total	(3.0)	(3.6)	(4.4)	(6.4)	(7.7)	(9.5)	(10.0)	(10.0)	(10.0)	(10.0)	(74.6)
TOTAL Monterey	(3.0)	(9.6)	(6.4)	(14.7)	(20.7)	(21.5)	(10.0)	(10.0)	(10.0)	(10.0)	(115.9)
OMAHA (AFGWC)											
Invest. Facilities	-	.3	1.1	-	-	-	-	-	-	-	1.4
Invest. EDP Equip.	-	4.8	-	-	13.0	12.0	-	-	-	-	29.8
Invest. Total		(5.1)	(1.1)	-	(13.0)	(12.0)	-	-	-	-	(31.2)
Ops-Communications	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	12.0
Ops-Pay & Allowances	5.9	6.1	7.2	7.5	8.4	9.0	9.7	9.7	9.7	9.8	83.0
Ops-Non-Pay Costs	1.7	1.7	2.0	2.0	3.0	3.7	4.3	4.3	4.3	4.3	31.3
Ops-Total	(8.8)	(9.0)	(10.4)	(10.7)	(12.6)	(13.9)	(15.2)	(15.2)	(15.2)	(15.3)	(126.3)
TOTAL AFGWC	(8.8)	(14.1)	(11.5)	(10.7)	(25.6)	(25.9)	(15.2)	(15.2)	(15.2)	(15.3)	(157.5)
OMAHA-SATELLITE DPF											
Invest. Facilities	-	4.1	1.0								5.1
Invest. EDP Equip.	-		12.0	1.0							13.0
Invest. Total		(4.1)	(13.0)	(1.0)							(18.1)
Ops-Communications	-	-	-	-	-	-	-	-	-	-	0
Ops-Pay & Allowances	-	.5	.9	1.3	1.3	1.3	1.3	1.3	1.3	1.3	10.5
Ops-Non-Pay Costs	-	-	-	1.2	1.5	1.5	1.5	1.5	1.5	1.5	10.2
Ops-Total		(.5)	(.9)	(2.5)	(2.8)	(2.8)	(2.8)	(2.8)	(2.8)	(2.8)	(20.7)
TOTAL Satellite DPF	-	(4.6)	(13.9)	(3.5)	(2.8)	(2.8)	(2.8)	(2.8)	(2.8)	(2.8)	(38.8)
GRAND TOTAL OPTION 2	(11.8)	(28.3)	(31.8)	(28.9)	(49.1)	(50.2)	(28.0)	(28.0)	(28.0)	(28.1)	(312.1)

Option 3 involves collocation and consolidation in one principal site of activities now accomplished separately at Fleet Numerical Weather Central and at Air Force Global Weather Central with the additional provision for meeting presently unmet needs. The major equipment complement for Option 3 is listed in Table 49. It involves four Class 4 equipments and two Class 3 equipments as well as memory storage capacity. These machines provide a total capacity of 130 seconds per second as compared to needs defined in this report of 112.6 seconds per second. Occurring because equipment capability occurs in specific sizes, the difference is a reserve for needs not specified in this study. During the interim prior to Site C becoming fully operation, 3 CDC 6500s are operated at Monterey and 2 Univac 1108 multiprocessors and 2 Univac 1110s are operated at Omaha.

TABLE 49. MAJOR EQUIPMENT COMPLEMENT FOR OPTION 3

	PROJECTED NEEDS (SEC SEC^{-1})	PROJECTED AVAILABILITY (SEC SEC^{-1})	
SITE C:			
TROPOSPHERE: MODELS, APPL	14.9	4 CLASS 4	120.0
		2 CLASS 3	10.0
SATELLITE: PHOTO & EMISSION	20.4		
			130.0
OCEANS: MODELS, APPL, BUOY SYSTEMS	24.4	$2\ 10^{10}$ BIT DISCS	
		1 CLIMATOLOGY STORE	
STRATO, MESO, THERMOSPHERE: MODELS, APPL	12.4	$1\ 10^{12}$ BIT REUSABLE BUFFER	
PROGRAM DEVELOPMENT & EQUIPMENT MAINTENANCE	40.5		
	112.6		
INTERIM SITE MONTEREY	4	3 CDC 6500	2.1
INTERIM SITE OMAHA	4	2 U-1108 MP	1.4
		2 CLASS 2	2.0
			3.6

The time plan for establishing the operations of Option 3 is shown in Fig. 29. In this option it is necessary to install additional equipment at Fleet Numerical Weather Central to meet present needs. This equipment, a third CDC 6500, can be crowded into the present location of equipments at Naval PG School.

The time plan for Option 3 also provides for the conversion of 2 Univac 1108s, of the present 4, to become U-1108 (MP) multiprocessors

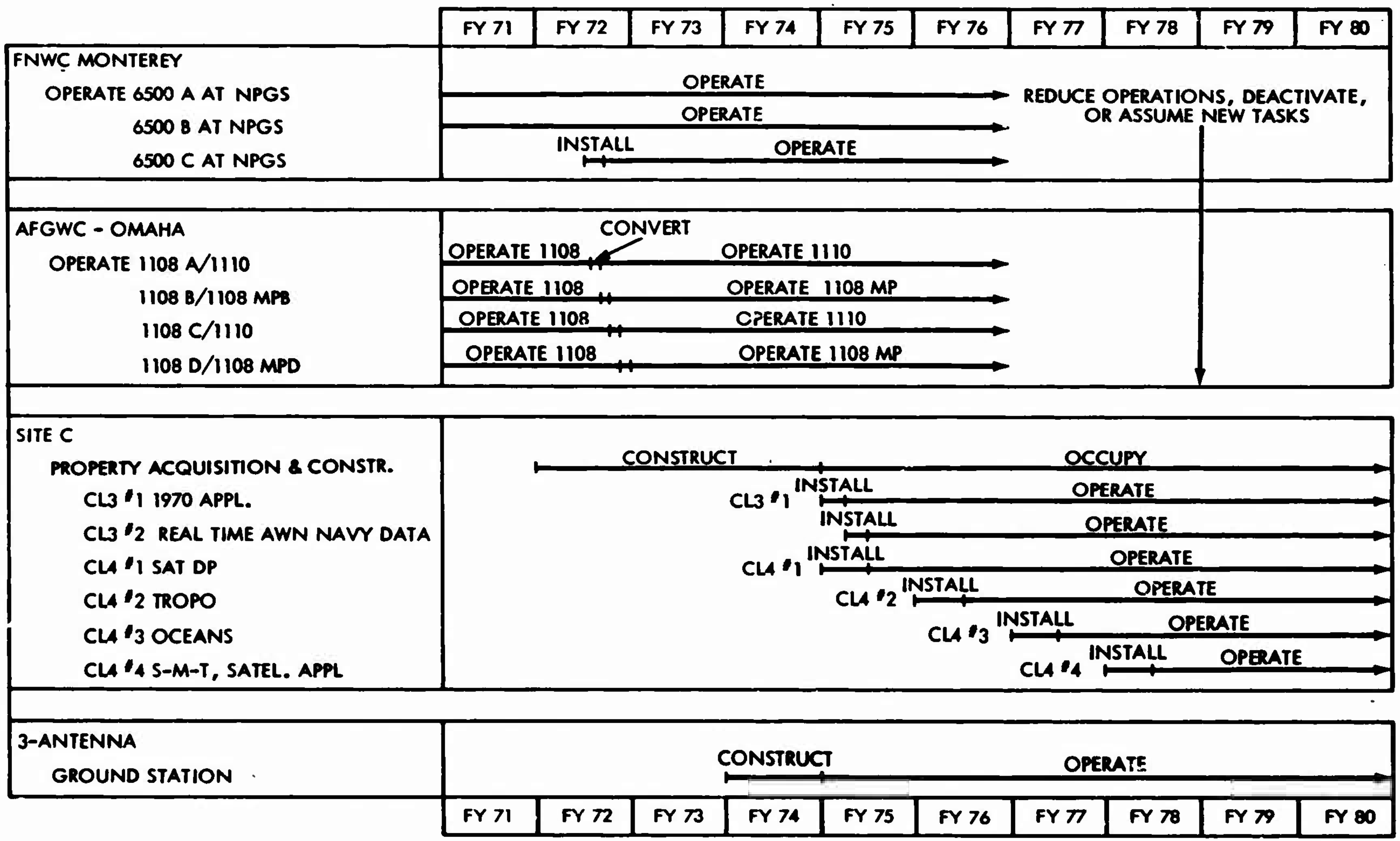

FIGURE 29. Time-Phased Plan for Option 3

and the conversion of the other 2 U-1108s to become the U-1110 equipments. This conversion is necessary to continue present operations of Air Force Global Weather Central at Omaha to meet expanding needs. These changes are in fact in some degree already in stages of planning. Option 3 also provides for the establishment of new equipments at a site not selected by this study. An important facet of the plan, however, is that the present operations at Global Weather Central at Omaha and Fleet Numerical Weather Central at Monterey continue to provide uninterrupted services during the interim before Site C is fully operational.

The site for location of the new big computers may be either Omaha or Monterey, or alternatively a third site. The detail of selection of an optimum site has not been undertaken by this study so hereafter the location of the major new equipments required for Option 3 will be referred to as Site C.

The selection and construction of Site C may begin in FY 1972 and the installation of equipments may begin early in FY 1975. The equipments to be installed, as shown in Fig. 29, are two Class 3 and four Class 4 equipments.

The installation of three 30-foot equivalent antennas to serve as the ground station for reception of satellite data is suggested to begin construction in FY 1974 and begin operation in FY 1975. Since earlier operation of satellite readout facilities is certainly desirable, interim installations not described in this study may therefore be required at AFGWC Omaha.

The personnel required for Option 3 are listed in Table 50. As may be seen, 175 people are required for interim operation until the end of FY 1976 at FNWC Monterey, and 592 people are required for interim operation at AFGWC Omaha, also ending in FY 1976. The addition of people to man Site C begins in FY 1973 and reaches a maximum of 1052 in FY 1980. Of the 1052, 587 are data processing personnel, 433 are production forecasters, observers, and supervisors of quality control, and 30 are required to operate the satellite data processing

TABLE 50. PERSONNEL FOR OPTION 3

	Actual FY 71	FY 72	FY 73	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79	FY 80
FNWC-Monterey Equipment	2_1^*	3_1	3_1	3_1	3_1	3_1	0			
A. Operators	39	59	59	59	59	59				
B. Maintenance and Engineering	22	28	28	30	30	30				
C. Systems Programmers	7	7	7	7	7	7				
D. Appl. Programmers	55	55	55	55	55	55				
E. Administration	15	18	18	19	19	19				
Subtotal (EDP)	138	167	167	170	170	170				
F. Meteor/Ocean Quality Control	5	5	5	5	5	5				
FNWC TOTAL	143	172	172	175	175	175	0			
							REASSIGN			
AFGWC-OMAHA Equipment	4_1	2_1+2_2	2_1+2_2	2_1+2_2	2_1+2_2	2_1+2_2	0			
A. Operators	95	95	95	95	95	95				
B. Maintenance and Engineering	11	11	11	13	13	13				
C. Systems Programmers	30	30	30	30	30	30				
D. Applications Prog.	78	88	88	88	88	88				
E. Administration	50	54	63	63	63	63				
Subtotal (EDP)	264	279	287	289	289	289				
F. Prod. Forecasters/Observors	228	228	303	303	303	303				
AFGWC TOTAL	492	506	590	592	592	592	0			
SITE C - Equipment	0	0	0	0	2_3+1_4	2_3+2_4	2_3+3_4	2_3+4_4	2_3+4_4	2_3+4_4
A. Operators	0	0	0	0	70	90	110	130	130	130
B. Maintenance and Engineering	0	0	0	7	13	20	28	28	28	30
C. Systems Programmers	0	0	0	63	66	69	72	72	72	72
D. Appl. Programmers	0	0	20	60	80	100	243	243	243	243
E. Administration	0	0	2	25	56	76	106	112	112	112
Subtotal (EDP)	0	0	22	155	285	355	559	585	585	587
F. Prod. Forecasters/Obs. Ocean/Meteor	0	0	0	77	209	321	403	433	433	433
B. Sat. Readout Function	0	0	0	0	30	30	30	30	30	30
EPRF R&D	0	0	20	40	60	60	60	60	60	60
TOTAL SITE C	0	0	42	272	584	766	1052	1108	1108	1110
Programmed Products	0	0	0	0	3	6	8+1970	10+1970	10+1970	10+1970
Total EDP	402	445	476	614	744	814	559	585	585	587
TOTAL OPTION 3	635	678	804	1039	1351	1533	1052	1108	1108	1110

*Refers to number and class of equipment, i.e., 2_1 is two Class 1 computers.

function. The costs of exercising Option 3 are listed in Table 51. The total cost of Monterey through the period until deactivation in FY 1977 involves $6.7 million in the peak of FY 1972 and after other investment costs have been made, annual costs level out at $3.8 million per year. Total costs for the fiscal years 1971 to 1976 are $24.9 million. Similarly, at Omaha, annual cost is $14.1 million in the peak year, leveling out with operation and maintenance costs of $10.3 million. Total costs over the period FY 1971 to 1976 aggregate $64.1 million.

Site C, including the satellite data processing function, has an annual costs in peak year 1975 of $39.6 million, leveling out to an operating and maintenance costs of $20.7 million per year. Total for the ten-year period ending in FY 1980 is $187.4 million. The grand total for all three centers has a maximum annual cost of $53.7 million in FY 1975, in leveling out operation and maintenance costs of $20.7 million and a total cost for the ten-year period of $276.4 million.

In Fig. 30 is shown a comparison of costs by site for data processing of the DoD environmental services support systems in 1975 to 1980. Shown in Fig. 30 are the costs for Options 1, 2, and 3. The annual cost for Option 0 for this ten-year period is judged to be $11.8 million per year and is the starting year cost for other options shown in the figure.

In Fig. 31 is shown a comparison of investment and operating costs for 1971 to 1980 under Options 1, 2, and 3. As may be seen graphically from Fig. 31, the investment costs for Options 2 and 3 are roughly comparable. More reserve capacity is provided in Option 2 simply by virtue of the fact that equipments cannot be procured except in certain sizes. The extra reserve capacity of Option 2 therefore represents capacity for further growth.

A comparison of the several alternatives may be summarized in the following way. A comparison of computer personnel required in 1980 for Options 0, 1, 2, and 3 is shown in Table 52.

TABLE 51. OPTION 3 COSTS FOR DATA PROCESSING OF DOD ENVIRONMENTAL SUPPORT SYSTEMS OF 1975-80

	FY 71	FY 72	FY 73	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79	FY 80	TOTAL (FY 71-80)
MONTEREY											
Invest. Facilities	-	.1	-	-	-	-	-	-	-	-	.1
Invest. EDP Equip.		3.0									3.0
Invest. Total	-	(3.1)	-	-	-	-	-	-	-	-	(3.1)
Ops-Communications	.5	.5	.5	.5	.5	.5	-	-	-	-	3.0
Ops-Pay & Allowances	1.7	2.1	2.1	2.1	2.1	2.1	-	-	-	-	12.2
Ops-Non-Pay Costs	.8	1.0	1.2	1.2	1.2	1.2	-	-	-	-	6.6
Ops-Total	(3.0)	(3.6)	(3.8)	(3.8)	(3.8)	(3.8)	-	-	-	-	(21.8)
TOTAL Monterey	(3.0)	(6.7)	(3.8)	(3.8)	(3.8)	(3.8)	-	-	-	-	(24.9)
OMAHA											
Invest. Facilities	-	.3	-	-	-	-	-	-	-	-	.3
Invest. EDP Equip.	-	4.8	-	-	-	-	-	-	-	-	4.8
Invest. Total	-	(5.1)	-	-	-	-	-	-	-	-	(5.1)
Ops-Communications	1.2	1.2	1.2	1.2	1.2	1.2	-	-	-	-	7.2
Ops-Pay & Allowances	5.9	6.1	7.1	7.1	7.1	7.1	-	-	-	-	40.4
Ops-Non-Pay Costs	1.7	1.7	2.0	2.0	2.0	2.0	-	-	-	-	11.4
Ops-Total	(8.8)	(9.0)	(10.3)	(10.3)	(10.3)	(10.3)	-	-	-	-	(59.0)
TOTAL - Omaha	(8.8)	(14.1)	(10.3)	(10.3)	(10.3)	(10.3)	-	-	-	-	(64.1)
SITE C (incl. Sat. DPF)											
Invest. Facilities	-	11.9	-	-	-	-	-	-	-	-	11.9
Invest. EDP Equip.					29.0	13.0	12.0	12.0			66.0
Invest. Total	-	(11.9)	-	-	(29.0)	(13.0)	(12.0)	(12.0)	-	-	(77.9)
Ops-Communications	-	-	-	.5	1.5	1.5	1.5	1.5	1.5	1.5	9.5
Ops-Pay & Allowances	-	-	.5	3.3	7.0	9.2	12.6	13.3	13.3	13.3	72.5
Ops-Non-Pay Costs	-	-	-	-	2.1	3.5	4.6	5.5	5.9	5.9	27.5
Ops-Total	-	-	(.5)	(3.8)	(10.6)	(14.2)	(18.7)	(20.3)	(20.7)	(20.7)	(109.5)
TOTAL Site C	-	(11.9)	(.5)	(3.8)	(39.6)	(27.2)	(30.7)	(32.3)	(20.7)	(20.7)	(187.4)
GRAND TOTAL OPTION 3	(11.8)	(32.7)	(14.6)	(17.9)	(53.7)	(41.3)	(30.7)	(32.3)	(20.7)	(20.7)	(276.4)

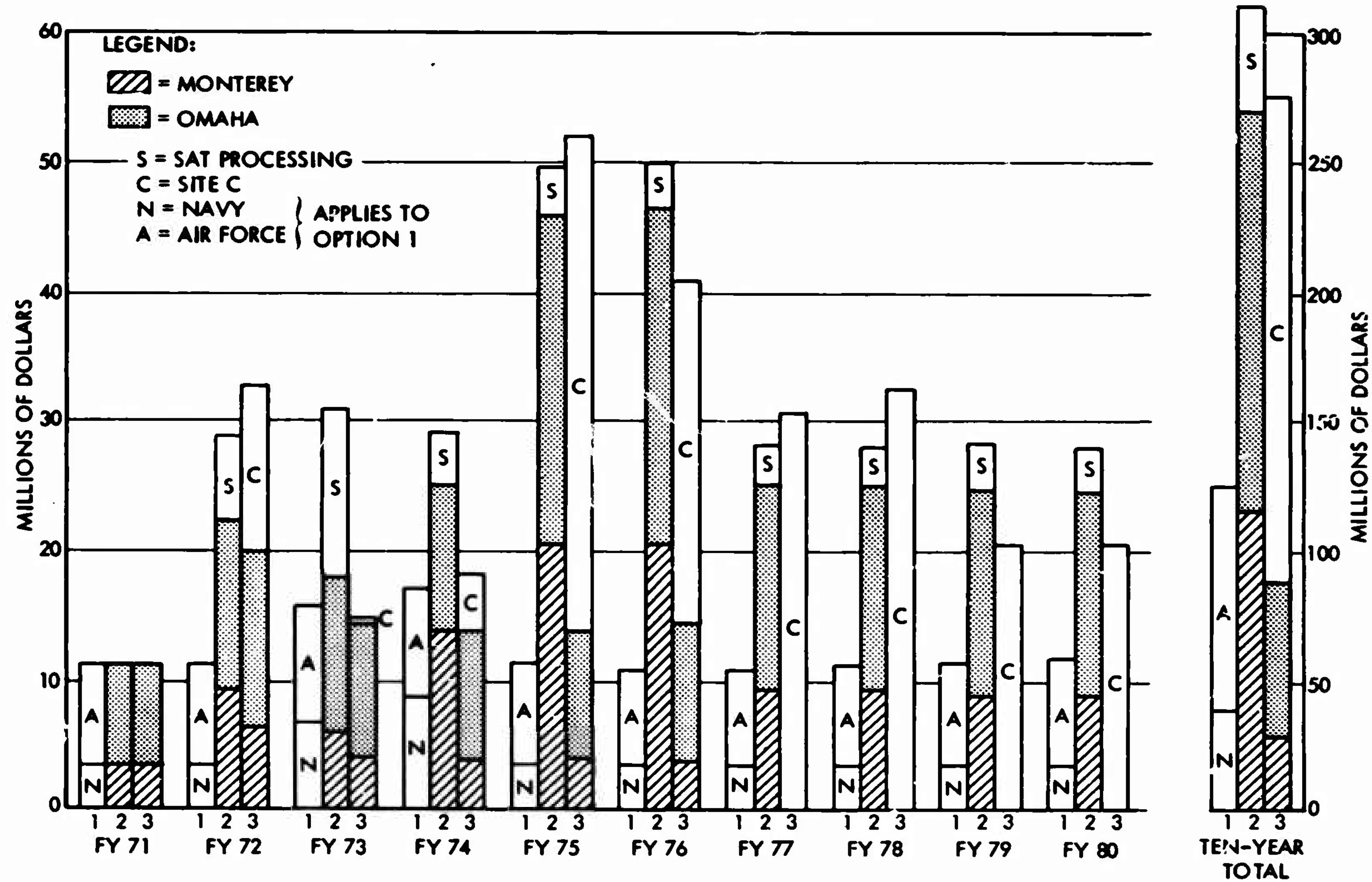

FIGURE 30. Comparison of Costs by Site for Data Processing of DOD Environmental Support Systems of 1975-80

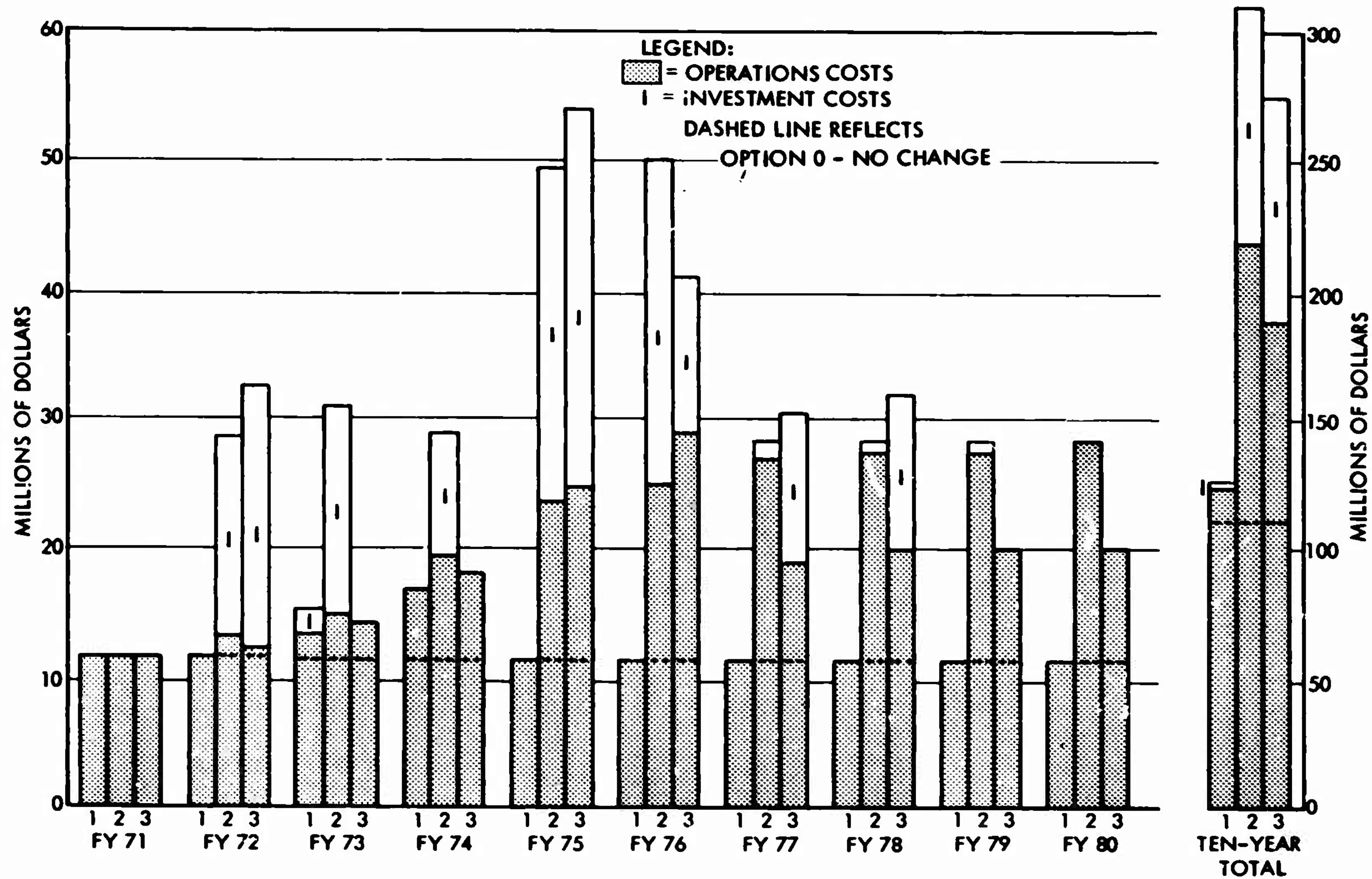

FIGURE 31. Comparison of Investment and Operating Costs for Data Processing of DOD Environmental Support Systems of 1975–80

TABLE 52. COMPUTER PERSONNEL, 1980

	OPERATORS	MAINT ENGR	SYST. PROG.	APPLIC.	TOTAL (INCLUDING ADMINISTRATIVE)
OPTION 0	134	CDC, UNIVAC + 33	37	133	402
OPTION 1	135	CDC, UNIVAC + 33	37	113	380
OPTION 2	274	CDC, UNIVAC + 69	96	243	830
OPTION 3	130	VENDOR + 30	72	243	587

Noted in Table 52 are numbers of operators, maintenance engineers, system programmers and application programmers required for each of the options. These differences are largely due to differences in types of numbers of machines used in each option.

To summarize the major equipment complement for the four options, Table 53 shows for each site of each option the following items: for each major computational program the numbers and types of satellites and ocean data collection platforms desirably providing data, the numbers and location of ground station readout receiving antennas, the computer capacity required, and for the site the computer and storage complement recommended to satisfy the capacity.

An overall comparison of the options in terms of computer staff, machines, and ten-year costs, and application areas is given in Table 54. In general, a comparison of Options 0/1 and Options 2/3 indicates that meeting the currently unmet needs with technically possible solutions will involve an overall budgetary increase of a factor of approximately 3.

TABLE 53. MAJOR EQUIPMENT COMPLEMENT FOR DOD OPTIONS 0, 1, 2 AND 3

OPTION/INCREMENTS	NUMBER OF SATELLITES A	B	C	D	E	DCP VIA SATELLITE C	NUMBER OF ANTENNAS AT SATELLITE READOUT STATIONS WEA. CEN.	EAST U.S.	ALASKA	HAWAII	CHILE	WEST AUSTR.	PROBLEM REQ (SEC SEC^{-1})	COMPUTER AND STORAGE COMPLEMENT	PROJECTED CAPACITY (SEC SEC^{-1})
OPTION 0															
SITE: MONTEREY													1.4	2 - CDC 6500	(3.0)
SITE: OMAHA													1.6	4 - SRU 1108	(3.0)
OPTION 1															
SITE: OMAHA													3.0	2 - CDC 6500 4 - SRU 1108	
OPTION 2															
SITE: MONTEREY															
a. TROPO: ANAL & PROG (PE MODEL) & CLIM. STOR.													8.3		
b. TROPO: NAVY APPLICATIONS OF 1970													3.3		
c. SATELLITE: PHOTOGRAPHIC & EMISSION														3 - CDC 6500	
d. OCEANS: OTHER FNWC APPLICATIONS (1970)													0.2	1 - CLASS 3	67.1
e. OCEANS: MODEL & CLIM. STORE													11.3	2 - CLASS 4	
f. OCEANS: NAVY APPL. (SOUND PROP.)													12.5	1 - CLIMATOLOGY STORE	
g. SATELLITE: BUOY SYSTEMS						3500							0.4	1 - 10^{10} BIT DISC	
h. S-M-T: MODEL & CLIM. STOR.													-	1 - 40,800 BAUD TELPAK	
i. S-M-T: NAVY APPLICATIONS													-		
j. SATELLITE: ABSORPTION													-		
k. SATELLITE: SOLAR MONITORING													0.01		
SUBTOTAL WITHOUT R & D						(3500)							(36.0)		
SUBTOTAL INCL. R & D (25%)													(9.0)		
													(45.0)		
DEAD TIME & MAINTENANCE (20% OF TOTAL FNWC)													11.3		
TOTAL FNWC													(56.3)		
SITE: OMAHA															
a. TROPO: ANAL & PROG (PE MODEL) & CLIM. STOR.													8.3		
b. TROPO: AF APPLICATIONS OF 1970													3.3		
c. SATELLITE: PHOTO & EMISSION	4		4		2		2	4	4	2			20.3		
d. AWN (1970 CAPACITY)													.04		
e. OCEANS: MODEL & CLIML STOR.													-	2 - SRU 1108 MP 3 - SRU 1110	
f. OCEANS: AF APPLICATIONS													-	3 - CLASS 4	93.4
g. SATELLITE: BUOY SYSTEMS													-	1 - CLIMATOLOGY STORE 1 - BUFFER 10^{12} STORE	
h. S-M-T: MODEL & CLIM. STOR.													10.0	2 - 10^{10} BIT DISCS	
i. S-M-T: AF APPL. (RADIO & SAT. DRAG)													2.4		
j. SATELLITE: ABSORPTION		4						2		2	2		.03		
k. SATELLITE: SOLAR MONITORING				3			1	1				1			
SUBTOTAL WITHOUT R & D	(4)	(4)	(4)	(3)	(2)		(3)	(7)	(4)	(4)	(2)	(1)	(44.4)		
SUBTOTAL INCL. R & D (25%)													(11.1)		
													(55.5)		
MAINTENANCE & DEAD TIME (20% OF AFGWC TOTAL)													13.9		
TOTAL AFGWC													(69.4)		
TOTAL OPTION 2	(4)	(4)	(4)	(3)	(2)	(3500)	(3)	(7)	(4)	(4)	(2)	(1)	(125.7)	ALL SHOWN	(160.5)
OPTION 3															
SITE: C															
a. TROPO: ANAL & PROG (PE MODEL) & CLIM. STOR.													8.3		
b. TROPO: NAVY & AF APPLICATIONS													6.6		
c. AWN 1970 CAPACITY													.04		
d. SATELLITE: PHOTO & EMISSION	4		4		2		2	4	4	2			20.3		
e. OCEANS: OTHER FNWC 1970 APPL													0.2		
f. OCEANS: MODEL & CLIM. STORE													11.3		
g. OCEANS: NAVY APPL. (SOUND PROP)													12.5	2 - CLASS 3	130.0
h. SATELLITE: BUOY SYSTEMS						3500							.4	4 - CLASS 4	
i. S-M-T: MODEL & CLIM. STOR.													10.0	1 - CLIMATOLOGY STORE 1 - BUFFER 10^{12} STORE	
j. S-M-T: AF APPL. (RADIO & SAT. DRAG)													2.4	2 - 10^{10} BIT DISCS	
k. SATELLITE: ABSORPTION		4						2		2	2		.03		
l. SATELLITE: SOLAR MONITORING				3			1	1				1	.01		
SUBTOTAL WITHOUT R & D	(4)	(4)	(4)	(3)	(2)	(3500)	(3)	(7)	(4)	(4)	(2)	(1)	(72.1)		
SUBTOTAL INCL. R & D (25%)													(18.0)		
													(22.5)		
DEAD TIME & MAINTENANCE (20% OF TOTAL)													90.1		
TOTAL OPTION 3													(112.6)		(130.0)
SITE: MONTEREY															
a. TOTAL INTERIM ANALYSES, PROG, APPLIC., R & D, DEAD													4.0	3 - CDC 6500	2.1
SITE: OMAHA															
a. TOTAL INTERIM ANALYSES, PROG, APPLIC., R & D, DEAD													4.0	2 - SRU 1108 MP 2 - SRU 1110	3.4
INTERIM TOTAL OPTION 3	(4)	(4)	(4)	(3)	(2)	(3500)	(3)	(7)	(4)	(4)	(2)	(1)	(120.5)	ALL SHOWN	(135.5)

TABLE 54. COMPARISON OF OPTIONS

	COMPUTER STAFF	MACHINES	TOTAL COST (FY 71-80) ($M)	APPLICATION
OPTION 0	402	8 CLASS 1	118	TROPO OCEANS
OPTION 1	380	8 CLASS 1	124	TROPO OCEANS
OPTION 2	830	5 CLASS 4 1 CLASS 3 2 CLASS 2 5 CLASS 1 1 CLIMATOLOGY STORE 1 10^{12} BIT REUSABLE BUFFER 2 10^{10} BIT DISC MEMORY	312	TROPO OCEANS S-M-T
OPTION 3	587	4 CLASS 4 2 CLASS 3 1 CLIMATOLOGY STORE 1 10^{12} BIT REUSABLE BUFFER 2 10^{10} BIT DISC MEMORY	276	TROPO OCEANS S-M-T

The pros and cons of each of the options are listed in Table 55. Option 0 has minimum cost but duplication of computer operation involves using 8 percent of the facilities twice. Option 0 is inadequate in meeting of needs.

Option 1 makes more easy professional cooperation between Services to accelerate the state of the art. It has the disadvantage of inadequately meeting needs at a cost that is greater than for Option 0. The elimination of the 8 percent of facilities used twice in Option 0 by Option 1 is not cost-effective, requiring the expenditure of about $7 million to effect a saving of about a half million per year.

Option 2 meets the operational needs, provides 23 percent more capacity than does Option 3 and has the additional feature of greater survivability of two sites. It provides for professional competition between the Services and is a "walk-before-you-run" step from the current management organization form. It also makes possible on-site

training easier than does Option 3. It is less vulnerable to controversy in the matter of site selection. Within the confidence limits of the estimating procedure, Options 2 and 3 are similar in costs and capacity.

The disadvantages of Option 2 are some duplication of computer capacity. The transition to and development of new software models for the Class 4 machines are more difficult. The key management problem involved in Option 2 concerns the satellite data processing function which must be responsive to the needs of both Services.

Option 3 has the advantages of meeting operational needs of 1975 and of easier harmonization of software compatibility than with Option 2. A further advantage of Option 3 is that the coordination is more easily accomplished if the computation installations are phased in time according to domains of interest. Option 3 makes easier professional cooperation between the Services and a smoother transition in the development of Class 4 models. Option 3 is within the confidence limits of the estimations, approximately the same in cost as Option 2.

A disadvantage of Option 3 is the money spent on interim computer capacity; Option 3 makes more difficult the on-site training prior to installation of the Class 3 and 4 machines. Option 3 invites public controversy in the selection of Site C, and management difficulties consequent on a radical change in organizational form.

TABLE 55. PROS AND CONS

OPTION 0	+	COST IS MINIMUM
	-	INADEQUATE MEETING OF NEEDS
	-	DUPLICATION OF COMPUTER OPERATION (8% OF FACILITIES USED TWICE)
OPTION 1	+	PROFESSIONAL COOPERATION BETWEEN SERVICES ACCELERATES STATE OF THE ART
	-	INADEQUATE MEETING OF NEEDS
	-	COST GREATER THAN OPTION 0
OPTION 2	+	MEETS OPERATIONAL NEEDS
	+	MORE RESERVE COMPUTER CAPACITY (23% MORE CAPACITY THAN OPTION 3)
	+	PERMITS CONTINUATION OF INNOVATIONS ALREADY INITIATED
	+	SURVIVABILITY OF TWO SITES
	+	PROFESSIONAL COMPETITION BETWEEN SERVICES
	+	ORGANIZATIONAL "WALK-BEFORE-YOU-RUN" MAKES SIMPLER MANAGEMENT TRANSITION
	+	MANAGEMENT PROBLEMS TO ACHIEVE SINGLE SERVICE RESPONSIVENESS ARE EASIER TO SOLVE
	+	EASIER ON-SITE TRAINING
	-	SOME DUPLICATION OF COMPUTER CAPACITY
	-	MANAGEMENT PROBLEM INVOLVED IN ASSURING COMPLETE RESPONSIVENESS OF SATELLITE DATA PROCESSING TO BOTH SERVICES
	-	HARD TRANSITION IN DEVELOPMENT OF MODELS FOR CLASS 4 MACHINES
OPTION 3	+	MEETS OPERATIONAL NEEDS
	+	HARMONIZATION OF SOFTWARE COMPATIBILITY EASIER THAN OPTION 2
	+	COORDINATION IS EASIER IF COMPUTATION INSTALLATIONS ARE PHASED BY DOMAINS OF INTEREST
	+	PROFESSIONAL COOPERATION BETWEEN SERVICES
	+	SMOOTH TRANSITION IN CLASS 4 MODEL DEVELOPMENT
	-	LESS FAMILIAR MANAGEMENT PROBLEMS OF JOINT OPERATIONS
	-	LESS RESERVE COMPUTER CAPACITY THAN OPTION 2
	-	COST OF INTERIM COMPUTER CAPACITY
	-	ON-SITE TRAINING MORE DIFFICULT
	-	PUBLIC CONTROVERSY POSSIBLE IN SITE SELECTION

VII. RECOMMENDATIONS

It is recommended that cost/benefit analyses of the military needs for environmental data be performed to determine the extent to which improved capabilities which are forecast to be technologically available in 1975-80 should be implemented.

If, on the basis of this analysis, the currently stated military needs are to be fully met, DoD should proceed with acquisition and installation of advanced computers and of satellite readout facilities for operational environmental services support at an investment cost over the next eight years of $90 million. Differences of physical realizability and cost between Option 2 (separate centers) and Option 3 (collocated/consolidated centers) are within the confidence limits of the estimation. The choice should be made on the basis of other management considerations.

If the stated military needs are to be met, the DoD should initiate studies to:

- Determine the optimum location of new sites.
- Determine the best way of exploiting and of augmenting satellite programs of the civil sector.
- Specify and select particular computers best suited for individual and collective operations.
- Maximize survivability of the DoD automated environmental services support systems, in the event of war and natural disaster. Provision of backup capability between the two centers should also be studied.

In addition, if the stated military needs are to be met, DoD should initiate two new equipment developments:

- A greatly expanded ocean data collection system utilizing ships and buoys in recognition of a current deficiency wherein only one percent of the ocean data estimated to be needed in 1975 is presently programmed to be available.

- A communication relay satellite system in recognition of the political limitations of the civilian INTELSAT which is unlikely to be dedicated to future military needs for relaying environmental data either from other satellites or from buoy sources.

In carrying out the implementation of Option 2 or 3, certain cautions should be observed:

- The estimates leading to the conclusions of this report are initial approximations not to be taken as a final definitive plan.

- To the extent possible within a broadly acceptable plan, Option 2 or 3 should be implemented in stages, testing the practicality of each step as it progresses.

- The sites recommended for satellite data processing and/or Site C should be chosen carefully in terms of the needs for security, provision of base support, allowance for space and growth, accessibility for communications, survivability from natural and war disasters, provision of living conditions for personnel, and provision for a highly desirable interaction of the professional staff with scientific and research community.

- Joint management should be encouraged in those cases where interests between the Services are shared in common; where Service interests differ, it should be ensured that management is maximally responsive to the users.

- Accessibility to the computational tools should be maximized for the environmental support service geophysicists.

GLOSSARY AND DEFINITIONS

ADWS	Automated Data Weather Switch
AEDS	Atomic Energy Detection System
AESC	Aerospace Environmental Support Center
AFGWC	Air Force Global Weather Central
AFSCF	Air Force Satellite Control Facility
analysis	the normalization of data to a specific time (synoptic time) and space grid of locations
archival storage device	a storage device capable of storing data for extended periods of time and in large volume
ARPA	Advanced Research Projects Agency
ART	Automatic Recording Thermograph
ASC-4X	Texas Instrument Co. Class 4 computer
AUTODIN	Automated Digital Network
AWN	Automated Weather Network
AWS	Air Force Weather Service
AXBT	Airdropped Experimental Bathythermograph
balance	AFGWC program of equipment improvement directed to achieving balance between central processor capacity and memory equipments
baud	a unit rate of data transmission approximately one word sec^{-1} or 32 bits sec^{-1}
bit	a unit of data in the binary system
CAT	clear air turbulence; collect and transmit unit

C&C Systems	Command and Control Systems
C&GS	Coast and Geodetic Survey (now included in NOAA)
CDC	Control Data Corporation
CDC 6500	computer equipment of vendor Control Data Corporation, used at FNWC Monterey
Class 1 machine	a computer, comparable to CDC 6500 and SRU 1108, corresponding in capacity (speed in response to instructions) to about half that of CDC 6600
Class 2 machine	a computer comparable in speed of response to instructions to the CDC 6600 and the SRU 1110 computers; that is, capable of responding to about 1 million instructions per second (MIPS)
Class 3 machine	a computer with speed of response to instructions about five times that of CDC 6600
Class 4 machine	a computer with speed of response to instructions about 30 times that of CDC 6600
computer capacity	speed in handling data, relative to that of CDC 6600, expressed in "sec sec^{-1}" (seconds of CDC 6600 operation per second of data in chronologic time), or in "MIPS" (millions of instructions per second)
CPU	Central Processor Unit
DCP	data collection platforms
DoD	Department of Defense
EPRF	Environmental Processing Research Facility
ESSA	Environmental Science Services Administration (now included in NOAA)
ETAC	Environmental Technical Applications Center

FNWC	Fleet Numerical Weather Central
FWC	Fleet Weather Central
FWF	Fleet Weather Facility
FY	fiscal year
GOES	Geostationary Observational Environmental Satellite (of NOAA)
grid point	space interval between computations of state at a given time
IDA	Institute for Defense Analyses
ILLIAC IV	a Class 4 computer designed by University of Illinois and fabricated by Burroughs Corp
INTELSAT IV	International Telephone Telegraph Co. Satellite
LUF	lowest usable frequency
MCAS	Marine Corps Air Station
mesosphere	the atmosphere at altitudes between the stratopause (the first temperature maximum occurring at about 50 kilometers) and the mesopause (the second temperature minimum occurring at about 90 kilometers)
military needs	needs for environmental services support data--not necessarily officially approved statement of military requirements
MIPS	millions of instructions per second
MUF	maximum usable frequency
multiprocessor computer (MP)	a computer with component serial computing units connected to a single large memory, controlled so that they may operate on the same or different instructions at any one time
NAS	Naval Air Station
NASA	National Aeronautics and Space Agency
NATC	Naval Air Training Center
NCAR	National Center for Atmospheric Research

NEDN	Naval Environmental Data Network
NOAA	National Oceanic and Atmospheric Administration
Oceans model	a computational model of the oceans based on hydro-, thermo-dynamic equations of continuity
ODESSA	Ocean Data Environmental Science Services Acquisition System
Option 0	a baseline alternative for DoD actions wherein no change is made to present operations at FNWC or AFGWC and no provision is made for meeting presently unmet needs in 1975
Option 1	an alternative for DoD action representing collocated or consolidated Navy and USAF operations at Omaha, with no expansion of capability to meet presently unmet needs in 1975
Option 2	an alternative of DoD action leading to separate Navy and USAF environmental services support systems, with expanded capability necessary to meet presently unmet needs in 1975
Option 3	an alternative DoD action leading to collocated or consolidated Navy and USAF environmental services support systems, with expanded capability necessary to meet presently unmet needs in 1975
OHD radars	over-the-horizon detection radars
ONR	Office of Naval Research
parallel processor computer	a computer organized to have a number of serial arithmetic units controlled by one central unit processing the instruction stream. Each arithmetic unit has its separate memory. Differs from the multiprocessor in requiring all arithmetic units to execute the same instruction at any one time
PMR	Pacific Missile Range

primitive equation model	a computational model of the troposphere based on hydro-thermodynamic equations of continuity
prognosis	a forecast based on a direction and other change from states of the atmosphere described by an analysis
radio propagation	the effect of atmospheric distributions
RAOBS	radiosonde observations
rotating storage devices	device for mass storage of data to which rapid access is required
RTOS	real-time operating system (a program of AFGWC)
satellite drag	the effect of density in decelerating satellites in orbit
SDPF	satellite data processing function
serial computer	a computer with one-to-one correspondence between instructions and results, which are produced serially
SESS	Space Environment Support System
SOLRAD Hi	one of SOLRAD 11 A/B/C, the eleventh in a series of solar radiations monitoring satellites developed under Aerospace of Naval Research Laboratory
sound propagation mapping	a technique for estimating and predicting ranges of detection by sonar equipment
SPASUR	Space Surveillance System
SMS	synchronous meteorological satellite of NASA
S-M-T model	a computational model of the stratosphere, mesosphere and lower thermosphere, based on hydro-thermodynamic equations described in Appendix E
SRU-1108	computer equipment of vendor Sperry Rand Univac; also referred to as U-1108; used at AFGWC

stratosphere	the atmosphere at altitudes between the tropopause (the first temperature minimum occurring at about 15 kilometers) and the stratopause (the first temperature maximum occurring at about 50 kilometers)
SUBOPCON	Submarine Operational Control Center
SXBT	Ships Experimental Bathythermograph
thermosphere	the atmosphere at altitudes above the mesopause (the second temperature minimum at about 90 kilometers)
TICUS	Tidal Current Survey
time step	time interval between computations of state at a single grid point
TIROS	Television Infrared Observation Satellite
troposphere	the atmosphere at altitudes below the tropopause, the first minimum of temperature as altitude increases. The tropopause occurs at about 15 kilometers in mid-latitudes
vector/pipeline computer	a computer arranged so that a single instruction to the arithmetic unit may operate in turn on a large number of operands brought in one sequence from memory (a "vector"). A different sequence of such instructions may operate at a number of stations in assembly line (a "pipeline"), so that suboperations on the operand vector may be assembled, permitting a continuous flow of operands at the memory cyclic rate.
VELA	a nuclear radiation detection satellite
WMO	World Meteorological Organization
window	AFGWC programs of analysis and prognoses on a fine mesh grid scale for one of: East Asia window; European window; U.S. window
word	a unit of data corresponding to about 32 bits